BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL

PRINCIPAL BENCH, NEW DELHI

Original Application No. 469/2025

IN THE MATTER OF:

Public Action Committee & Ors. **...Applicant**

Versus

Union of India & Ors. **...Respondent**

(s)

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Respondent No. 2

Filed by

New Delhi
Dated . 06-03-2026

GIGI. C. GEORGE
Advocate
NATIONAL GREEN TRIBUNAL
Email: gigicgeorge.adv42@yahoo.in
M-9810625315

BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL

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REPLY BY WAY OF AFFIDAVIT ON BEHALF OF RESPONDENT NO.1 AND 2

It Most Respectfully Showeth:-

1. That the present reply is being filed by Respondent No. 2 **Central Water Commission (CWC)** through Nagendra Kumar Singh, Executive Engineer, Central Water Commission, DoWR,RD&GR, Ministry of Jal Shakti, Government of India office at New Delhi, who is duly authorized and competent to file the present reply on behalf of the answering respondent no. 1 & 2.

2. That I am, in my aforementioned official capacity, well conversant with the facts and circumstances of the present case, based on the records and documents available with the department. As such, I am competent and authorized to swear and file the present reply affidavit on behalf of the Respondent No. 1 & 2 i.e. Ministry of Jal Shakti and Central Water Commission.

3. That present Original Application has been filed by the Public Action Committee and others before the Hon'ble National Green Tribunal, raising issues of environmental mismanagement and non-compliance

NOTARY S.K. PANDEY ADVOCATE NCT of Delhi Reg. No. 42533 Exp. 26.03.2030 GOVT. OF INDIA

with statutory norms. The application alleges mismanagement of Bhakra and Pong Dams by the Bhakra Beas Management Board (BBMB) and the State of Punjab, resulting in avoidable floods in Punjab during 2023 and 2025 and causing serious environmental and ecological damage. It is contended that BBMB continues to operate the reservoirs on outdated rule curves framed in 1990, despite revised Probable Maximum Flood data and advancements in weather forecasting, amounting to gross negligence and violation of the right to life under Article 21. The application seeks appropriate directions, accountability, and compensation under the National Green Tribunal Act, 2010 and other environmental laws.

PARA-WISE REPLY

4. That it is respectfully submitted that pursuant to flood events experienced in the States of Punjab and Uttarakhand during the year 2023, the Department of Water Resources, River Development & Ganga Rejuvenation (DoWR, RD&GR), Ministry of Jal Shakti, Government of India, vide Office Memorandum No. Z-15014/2/2023-FM Section–MoWR dated 04.09.2023, constituted a Committee under the Chairmanship of Chairman, CWC for conducting a joint flood management study in the said States. The copy of the said OM dt.04.09.23 is annexed as **Annexure-A.**

5. That the aforesaid Committee, comprising members from the affected State Governments and other expert organizations, conducted detailed technical studies and deliberations and submitted its report on 09.09.2024 to DoWR, RD&GR, Ministry of Jal Shakti and all concerned stakeholders for compliance. The recommendations of the Committee are advisory and technical in nature and aimed at strengthening overall flood management mechanisms. The copy of the recommendation of the committee is annexed as **Annexure-B.**

6. That the CWC has already carried out comprehensive flood routing studies for Bhakra and Pong Dams to assess the ability of the spillways and reservoirs to safely handle extreme flood events under various operational scenarios. These studies include assessment of reservoir water level responses, spillway discharge capacities, downstream flood impacts, and structural safety of the dams. The Maximum Reservoir Levels attained during floods of different return periods have been duly indicated. The said studies have already been shared with Bhakra Beas Management Board (BBMB) for reference and safe operation of the dams. The report of the study carried out by CWC is annexed as **Annexure-C.**

7. That the Committee has emphasized that Decision Support Systems (DSS) and Early Warning System (EWS) forecasts are indispensable for the effective management of large reservoirs such as Bhakra and Pong. These tools enable informed and timely decision-making, optimize reservoir operations, enhance safety, and reduce downstream flood impacts, thereby improving flood resilience and operational efficiency.

8. That the Flood Plain Zoning is a statutory and administrative responsibility of the respective State Governments. Formulation, enforcement, and regulation of land use in flood-prone areas are essential to minimize flood damages and safeguard life and property. The Hon'ble Supreme Court and this Hon'ble Tribunal have consistently held that regulation of development in flood plains falls within the jurisdiction of the State Governments, and not with technical advisory bodies such as CWC.

9. That effective operation and maintenance of embankments require regular visual and instrumental inspections supported by modern monitoring technologies and timely maintenance measures to address erosion, vegetation growth, seepage, and structural distress. Based on DEM-based flood carrying capacity assessments, evaluation of embankment

adequacy, including height, is required to be undertaken by the concerned State Departments. States are also required to maintain updated Emergency Action Plans (EAPs) and Standard Operating Procedures (SoPs) in compliance with prescribed norms. The Indian Standard IS:11532, relating to construction and maintenance of river embankments, provides necessary guidelines for pre-monsoon and monsoon maintenance.

10. That vide the same Office Memorandum dated 04.09.2023, review of rule curves of Bhakra and Pong Dams was included as one of the Terms of Reference of the Committee. Accordingly, revised rule curves were prepared based on long-term inflow data of approximately 30–40 years and information provided by BBMB, and a draft report was submitted to BBMB in June 2024.

11. That the rule curve represents the target reservoir water levels to be maintained during different periods of the year based on probabilistic assessment of inflows and water demands. The rule curve does not mandate or prescribe exact quantities of water to be released at any given time.

    Actual reservoir releases are determined dynamically during real-time operations based on prevailing inflows, forecasted rainfall, downstream river carrying capacity, flood moderation requirements, and irrigation and hydropower demands.

12. That the CWC functions as a technical advisory body, whereas implementation of flood control measures, flood plain zoning, embankment maintenance, and disaster response lie within the domain of the respective State Governments.

13. That in view of the above stated facts, it is most respectfully prayed that this Hon'ble Tribunal may be pleased to take the present affidavit reply on record and pass such further order(s) as deemed fit and proper in the facts and circumstances of the case.

05/03/26

DEPONENT

अधिशासी अभियंता/Executive Engineer
ऊपरी यमुना मण्डल/Upper Yamuna Division
केंद्रीय जल आयोग/Central Water Commission
नई दिल्ली-110016/New Delhi-110016

Verification

0 5 MAR 2026

I, Nagendra Kumar Singh, do hereby verify on 5th March 2026 at New Delhi the contents of the above paragraphs which are true to my own knowledge and/or are in the nature of legal submissions which I believe to be true and no material has been suppressed herewith.

I identify the Executant/deponent who has signed/Put T.I. in my presence

NOTARY
S.K. PANDEY
ADVOCATE
NOT of Delhi
Reg. No. 48663
Exp. 28.03.2030
GOVT. OF INDIA

ATTESTED
NOTARY PUBLIC
GOVT OF INDIA

0 5 MAR 2026

05/03/26

DEPONENT

अधिशासी अभियंता/Executive Engineer
ऊपरी यमुना मण्डल/Upper Yamuna Division
केंद्रीय जल आयोग/Central Water Commission
नई दिल्ली-110016/New Delhi-110016

mail sent

CE(FM) उ./Sec./निदे./Dte.
डा.सं./Dy. No. 495
दिनांक/Date 6/9/2023

Government of India
Ministry of Jal Shakti
Department of Water Resources, RD&GR
(Flood Management Wing)

Block-11, 8th Floor, CGO Complex,
Lodhi Road, New Delhi-110003.
Dated: 4th September, 2023

सदस्य (नदी प्रबंध) के.ज.आ. Member (RM) C.W.C. डा.सं. Dy.No. 1055 दिनांक Date 5/9/23

विषय: Constitution of a Committee for joint flood management study in wake of the extensive floods in the States of Himachal Pradesh, Punjab and Uttarakhand in 2023- reg.

The extensive flooding in the state of Himachal Pradesh, Punjab and Uttarakhand in 2023 necessitated a review of issues related to flood management in these States. In this regard, the undersigned is directed to convey that, with the approval of the competent authority of DoWR, RD&GR, Ministry of Jal Shakti, a Committee is constituted for conducting a ***joint flood management study in wake of the extensive floods in the state of Himachal Pradesh, Punjab and Uttarakhand***, as per the following composition:

1.	Chairman, Central Water Commission	Chairman
2.	Member (RM), Central Water Commission	Member
3.	Member (D&R), Central Water Commission	Member
4.	Commissioner (FM), DoWR, RD&GR, MoJS	Member
5.	Director, NWIC	Member
6.	JS (Hydro), Ministry of Power	Member
7.	Chairman, BBMB, Chandigarh	Member
8.	Chief Engineer, IBO, CWC, Chandigarh	Member
9.	Secretary, Irrigation & Public Health Department (Jal Shakti Vibhag),Govt. of Himachal Pradesh	Member
10.	Engineer in Chief, Irrigation &Public Health Department (Jal Shakti Vibhag), Govt. of Himachal Pradesh	Member
11.	Principal Secretary, Department of Water Resources, Govt. of Punjab	Member
12.	Chief Engineer, Department of Water Resources, Govt. of Punjab	Member
13.	Secretary, Irrigation Department, Govt. of Uttarakhand	Member
14.	Engineer in Chief, Irrigation Department, Govt. of Uttarakhand	Member
15.	Director, CW&PRS, Pune	Member
16.	Representative of NRSC, Hyderabad	Member
17.	Representative of IMD	Member
18.	Chief Engineer (FMO), Central Water Commission	Member-Secretary

2. The committee shall have the following Terms of Reference:

Z-15014/2/2023-FM Section-MOWR

I/87733/2023

i. Feasibility study of establishing HO sites and flood forecasting sites in the catchment of Sutlej and Beas rivers.
ii. Integrating the Inflow/Flood Forecasting network of BBMB to the platform of WIMS/NWIC.
iii. Examining and Review of Rule curves of Pong and Bhakra Dams.
iv. Studying the feasibility of better flood plain management and recommending measures to avoid encroachment of channels downstream of the dams to maintain its design discharge capacity.
v. Recommending measures for better O&M of embankments to prevent breaches causing damages.

3. The Committee will submit its final report within a period of 6 months from the date of its constitution.

4. The Committee may co-opt other members, if required, and may invite any officer from expert organizations.

5. The expenditure on TA/DA etc. of the officials for participating in meetings/visits shall be borne by the respective Organizations.

4/9/2023

Sr. Joint Commissioner-II (FM)
Ph.No.011-24362160
e-mail:sjcer2-mowr@nic.in

To

The Members of the Committee

Copy for information to:

1. Chief Secretary, Government of Punjab
2. Chief Secretary, Government of Himachal Pradesh
3. Chief Secretary, Government of Uttarakhand
4. Director General, IMD
5. Director, NRSC, Hyderabad.

4/9/2023

Sr. Joint Commissioner-II (FM)

Copy for kind information to:

1. PS to Hon'ble Minister for Jal Shakti
2. Sr.PPS to Secretary(WR,RD&GR)
3. Sr.PPS to Special Secretary(WR,RD&GR)

4/9/2023

Sr. Joint Commissioner-II (FM)

T-10075/2/2023 -FFM Part(1) dt. 08/12/2023

Annexure-B

भारत सरकार
जल शक्ति मंत्रालय
जल संसाधन, नदी विकास और गंगा संरक्षण विभाग
केंद्रीय जल आयोग
बाढ़ पूर्वानुमान प्रबोधन निदेशालय

सत्यमेव जयते

Government of India
Ministry of Jal Shakti
Department of Water Resources, River Development and Ganga Rejuvenation
Central Water Commission
Flood Forecast Monitoring Directorate

विषय: Minutes of 1st meeting of the Committee for joint flood management study in wake of the extensive floods in the state of Himachal Pradesh, Punjab and Uttarakhand in 2023.

महोदय,

Please find enclosed the approved Minutes of 1st meeting of the Committee for for joint flood management study in wake of the extensive floods in the states of Himachal Pradesh, Punjab and Uttarakhand held on 21/11/2023 at CWC, New Delhi-110066.

Encls: As above.

भवदीय,

8/12/23

बी के कारजी
मुख्य अभियंता (FMO) एवं मेम्बर सेक्रेटरी

प्रतिः

1. PPS to Chairman, CWC
2. PPS to Member (D&R), CWC
3. PPS to Member (RM), CWC
4. Commissioner, FM, DoWR, RD&GR, MoJS
5. Director, NWIC
6. Joint Secretary (Hydro), Ministry of Power
7. Chairman, BBMB, Chandigarh
8. Chief Engineer, IBO, CWC, Chandigarh
9. Secretary, Irrigation & Public Health Department, Govt. of Himachal Pradesh
10. Engineer in Chief, Irrigation & Public Health Department, Govt. of Himachal Pradesh
11. Principal Secretary, Department of Water Resources, Govt. of Punjab.
12. Chief Engineer, Department of Water Resources, Govt. of Punjab
13. Secretary, Irrigation Department, Govt. of Uttarakhand
14. Engineer in Chief, Irrigation Department, Govt. of Uttarakhand
15. Director General, IMD.
16. Director, CW&PRS, Pune.
17. Director, NRSC, Hyderabad.
18. Chief Engineer, UGBO, CWC, Lucknow (Special Invitee)
19. Chief Engineer, P&D/HSO/BPMO, CWC (Special Invitee)

विंग-7, भूमि तल
पश्चिमी खंड-2, राम कृष्ण पुरम
नई दिल्ली- 110066
दूरभाष- 011-26106523,26105274,26182836
ईमेल : fmdte@nic.in
जल सरंक्षण – सुरक्षित भविष्य

Wing-7,GroundFloor,
WestBlock-2,RKPuram,
NewDelhi– 110066
Tele 01126106523, 26105274, 26182836
Email : fmdte@nic.in
Conserve Water – Save Live

Minutes of 1st meeting of the Committee constituted for joint flood management study in wake of the extensive floods in the States of Himachal Pradesh, Punjab and Uttarakhand in the year 2023

The first meeting of the Committee constituted vide Department of Water Resources, River development and Ganga Rejuvenation, Ministry of Jal Shakti OM no Z-15014/2/2023-FM Section-MOWR dated 04.09.2023 for joint flood management study in wake of the extensive floods in the States of Himachal Pradesh, Punjab and Uttarakhand in 2023was held on 21st November, 2023 Sewa Bhawan, RK Puram, New Delhi-110066 under the chairmanship of Shri Kushvinder Vohra, Chairman, Central Water Commission & Ex-Officio Secretary to the Government of India.

The list of the participants attended the meeting is enclosed as **Annexure.**

2. At the outset, Chairman, Central Water Commission welcomed all the participants and gave a brief introduction of the agenda items for the meeting highlighting the various factors which might have caused flooding in these regions. He emphasized the important key issues like the early warning systems in place, effective response system, channel capacity, reason for continuous loss of channel capacity to route the flood etc. After the opening remarks of Chairman, CWC the members were then requested to give presentation on in wake of recent flooding incidence so as to know their views and suggestions in context to the ToRs of the constituted Committee. The presentations were then made by representatives of IMD, Himachal Pradesh, BBMB, Punjab and Uttarakhand.

3.1 Representative from IMD made a presentation on information compiled in wake of 2023 floods in HP, Punjab and Uttarakhand. He stated that in India, flood forecasting activity is the joint responsibility of India Meteorological Department and Central Water Commission. IMD provides Hydromet Input through their Flood Forecasting Offices (FMOs) mainly in the form of Quantitative Precipitation Forecast (QPF) to CWC, issuing Hydromet Bulletins by FMOs for both forecasted and Observed data and shares the NWP model based gridded rainfall forecast with BBMB. He also presented weather conditions responsible for the extreme heavy rainfall during 5-15 July, 2023, Daily & Cumulative rainfall from 5 July to 15 July, 2023 etc.

3.2 Chief Engineer, Jal Shakti Vibhag (JSV), Himachal Pradesh showed network of existing basin wise Hydro-meteorological Stations in the State of Himachal Pradesh and informed that data received from HO Stations is being uploaded on Water Information Management System (WIMS). She further informed that in order to avoid unauthorized encroachments of River/Khad beds & better Flood Plain Management, Himachal Pradesh has drafted Flood Plain Zoning Act, which is currently under the consideration of the State Govt of Himachal Pradesh for enacting legislation.

3.3 Secretary, BBMB presented the graphs of inflow, outflow and reservoir levels of Bhakra and Pond dam during the three extreme rainfall events that occurred on9-12 July, 12-16 Aug, 22-24 and Aug, 2023.He also suggested to study a complete Hydro-dynamic Model with 2D flood mapping of downstream areas with precise elevations so that vulnerable areas can be identified and accordingly Emergency Action Plan (EAP)/Disaster management plan (DMP) could be implemented. He was of the view, that downstream carrying capacity of rivers and khads should be restored and encroachment removal in drainage paths requires short term as well as long term measures. He expressed that the embankments and levees needs to be strengthened/repaired so as to sustain the designed floods along the river/ drainage system at vulnerable locations.

3.4 Chief Engineer, Water Resource Department, Government of Punjab in his presentation informed that the reason for floods in Punjab is mainly due to unprecedented rainfall in the catchment and showed photographs of damages to embankment, canals, CD structures, etc. He informed that the notifications on obstructions/ encroachment for River Sutlej under district Ferozepur, Tarn Taran, SBS Nagar, Moga and Jalandhar have been issued. This Notification will give power to concerned officer to remove obstructions/ encroachment in rivers or drains. He further informed that works are in progress in respect of Flood Plain Zoning of Rivers and Drains as per NDMA Guidelines, 2008 as well as on identification of encroachment in the rivers to maintain the design discharge capacity of river.

3.5 Chief Engineer, Irrigation & Drainage, Government of Uttarakhand showed the pictures of problems like rain cuts, toe/side slope failure & top erosion of embankments during this year flood near Haridwar.

After detailed discussions, the following tasks have been identified to be completed by the organizations in a time bound manner.

(i) a) Actual daily rainfall data that has occurred during the months of July and August 2023 to be furnished at basin and sub-basin scale. A comparative study of forecasted rainfall during the said period with actual rainfall may be carried out.

b) Analysis of historical data to obtain extreme rainfall for such events.

These tasks are to be completed by IMD **latest by 15.12.2023.**The results of the analysis would then be shared with HSO, CWC.

[Action: IMD/HSO, CWC]

(ii) Representative of Himachal Pradesh informed Master Plan on Hydro-meteorological stations in the State of Himachal Pradesh is available with the Department. The same to be shared with IBO, CWC and Member Secretary of committee **latest by 15.12.2023** duly indicating existing and proposed stations.

[Action: Himachal Pradesh/IBO, CWC]

(iii) Master Data Sheet of HO network under all the agencies i.e. BBMB, HP, Punjab, Uttarakhand to be prepared **by 15.12.2023**. Requisite information shall be provided by concerned agency to CE IBO, CWC and Member Secretary of the committee.

[Action: IBO, CWC/concerned agencies]

(vii) Representative of Himachal Pradesh informed that a Draft Flood Plain Zoning Bill has been prepared by the State. The same may be shared with CWC **by 15.12.2023**

[Action: Himachal Pradesh/RC Dte, CWC]

(viii) Representative of Punjab Govt. explained that the embankments are in place but there was overtopping downstream of the Bhakra and Pong dams during these events. It was brought to the notice of the committee that cross section surveys have been done by CWC in 2013 for Sutlej river for a morphological study conducted by NIH, Roorkee.

CWC to take up the matter with NIH to obtain the status of the work and to invite NIH in the next meeting as special invitee.

[Action: IBO, CWC/NIH]

(ix) CE, IBO informed that WRD, Punjab has done survey and also notified areas under flood plains. He was of the view that information on the data collected and notification issued will be useful for the committee's work as well as to supplement NIH's study.

WRD, Govt. of Punjab to provide the data collected during the survey and details of notification regarding Flood Plain demarcation. Punjab Govt. was directed to carry out survey in their jurisdiction to obtain DEMs and cross sections (embankment to embankment where applicable). WRD, Govt. of Punjab will also provide details on channel capacity, embankments, and encroachments, along with demarcation for different return period floods. This exercise for obtaining cross sections, embankments details etc. will also be carried out by Himachal Pradesh in their jurisdiction. This above information is required to be submitted with appropriate geo-referencing. This exercise is to be completed latest by **31.01.2024.**

[Action: Punjab/Himachal Pradesh]

(x) BBMB officials informed about the Decision Support System (DSS) and its utilization for flood forecast. It was desired to look into its working and the quality of forecast being generated along with the inputs used. It was decided that FCA-I/IIDte, CWC will jointly examine with NHP division of BBMB the functioning and efficacy of DSS.

[Action: BBMB/FCA-I/II Dte, CWC]

(xi) BBMB informed that the reservoirs have provided flood moderation during the July and August events. For effective regulation of reservoirs, review of rule curves of Pong and Bhakra Dam is required to be taken up by RO Dte of CWC in

consultation with BBMB. The data required for this analysis may be sent by BBMB immediately. BBMB to provide the requisite information, existing rule curves/reservoir operations and gate operation mechanism **by 15.12.2023**.

[Action: BBMB/RO Dte, CWC]

(xii) Emphasis on the requirement of automation of the gate operations of the reservoirs was desired and in this respect BBMB to submit a note on mechanism followed in gate operations for Bhakra and Pong dams and status of its automation.

[Action: BBMB/RO dte, CWC]

(xiii) Chairman, CWC requested Uttarakhand officials to examine adequacy of the HO network w.r.t the rainfall events occurred in last few years. In view of that Irrigation Deptt, Govt. of Uttarakhand is to analyse the adequacy of the HO network and to suggest any expansion/review of the network. During the next meeting detailed presentation may be given by Uttarakhand regarding their Flood Plain Zoning and area demarcation; HO network optimization (deletion/addition), GLOF studies, etc.

[Action: Uttarakhand]

(xiv) Other Items:

- IMD and NWIC to establish a mechanism to ensure sharing of real time RF data of stations/gridded received by NWIC.

[Action: IMD/NWIC]

- An MoU is in process for real time rainfall data transfer between CWC and IMD. This MoU to be examined and expedited by P&DO, CWC.

[Action: IMD/P&DO, CWC]

- MoU for integration/sharing of data between BBMB and HP is under renewal. The same may be expedited by BBMB and HP to ensure seamless data sharing is in place.

[Action: Himachal Pradesh/BBMB]

- BBMB raised a query about calculations of PMF at Pandoh and Pong dams.HSO and BBMB to discuss the design floods and PMF calculations for Pandoh and Pong dams for the clarifications of BBMB.

[Action: BBMB/ HSO, CWC]

- The khads and local nallahs/rivulets in the catchments also contribute to floods in the HP with very less lead time due to steep topography. It was pointed out that marking of HFLs can be first step aspect towards providing warning.HFL for all nallahs/rivulets and khads should be marked by the HP.

[Action: Himachal Pradesh]

- It was brought to the notice of the committee that Snow and Avalanche Study Establishment (SASE) center calculates snow water equivalent in sites in HP. As the information on snow melt runoff is crucial for reservoir operations therefore, It was decided that BBMB and IBO, CWC officials may visit SASE to understand the working of their snow gauging mechanism.

[Action: BBMB/IBO, CWC]

- NRSC to prepare a detailed note on “Availability and usability of DEM products developed by NRSC” for these three states in context to the ToR of the committee.

[Action: NRSC]

4. Chairman of the committee desired that following officials from agencies/State Govt may also be invited in the 2nd meeting as Special invitee for their inputs.
   (a) Uttarakhand - Officials from IRI, Roorkee and State Disaster Management
   (b) Himachal Pradesh -HPPCL and State Disaster management
   (c) Sutlej Jal Vidyut Nigam Limited (SJVNL), National Hydro Power Corporation (NHPC), National Institute of Hydrology (NIH) and Jindal South West (JSW)

Chairman of the Committee desired that the meeting may invariably be attended by the officials not below the rank of Engineer-in-Chief and also any representative attending the meeting should be authorized to put forth the views of respective Government in the meeting. The next meeting of the committee shall be held shortly to review the progress on all identified action points.

Meeting ended with vote of thanks to the Chair.

****

Annexure

Participants of 1st meeting of the Committee constituted for joint flood management study in wake of the extensive floods in the States of Himachal Pradesh, Punjab and Uttarakhand in the year 2023.

A. Department of Water Resources, River Development and Ganga Rejuvenation and Central water Commission

1. Shri Kushvinder Vohra, Chairman & Ex-Officio Secretary to Government of India
2. Shri S.K. Sibal, Member (D&R)
3. Shri P.M. Scott, Member (RM)
4. Shri D.P. Mathuria, Chief Engineer (P&D)
5. Shri Anupam Prasad, Chief Engineer UGBO
6. Shri B.K. Karjee, Chief Engineer (FMO)
7. Shri P. Dorjee Gyamba, Chief Engineer (POMIO)
8. Shri Rakesh Kashyap, Chief Engineer (IBO)
9. Shri Manoj Tiwari , Chief Engineer (HSO)
10. Shri N.N. Rai , Director, HYD (NE)
11. Shri Rajesh Kumar, SJC-II, FM
12. Shri Deepak Kumar, Director, RC Dte
13. Shri RiteshKhattar, Director, FCA-2 Dte
14. Shri RakeshToteja, Director, RDC-1 Dte
15. Shri Amitabh Meena, Director, RO Dte
16. Shri Manoj Kumar, Deputy Director, FFM Dte

B. Ministry of Power

1. Shri Arun Kumar Garg, Director (Hydro-II)

C. **CWPRS (through VC)**

1. Shri R S Kankara, Director

D. IMD

1. Shri A K Das, Scientist 'E'

E. NRSC

1. Dr. A. V. Suresh Babu, Head, Flood Mapping & Hazard Assessment

F. NWIC

1. Shri Anmol Sharma, Jt Director

G. BBMB

1. Shri Manoj Tripathi, Chairman
2. Shri Satish Singla, Secretary

H. Himachal Pradesh

1. Smt. Anju Sharma, Chief Engineer

I. Punjab

1. Shri H.S. Mendiratta, Chief Engineer, Drainage
2. Shri Kewal Kushan, Executive Engineer

J. Uttarakhand

1. Shri Prem Singh Panwar, Chief Engineer, I.D.
2. Shri Dixant Gupta, Executive Engineer
3. Shri Gaurav Goel

Government of India
Central Water Commission

Operation Rules (Rule curve)

for

Bhakra and Pong Dam

June 2024

1. Introduction

Joint flood management study in wake of the extensive floods in the States of Himachal Pradesh, Punjab and Uttarakhand in the year 2023

The extensive flooding in the state of Himachal Pradesh, Punjab and Uttarakhand in 2023 necessitated a review of issues related to flood management in these states. In this regard, DOWR, RD & GR constituted a committee under Chairman, CWC for conducting the study with one of the TOR as Review of Rule Curves of Pong and Bhakra Dam for effective regulation of reservoirs.

The committee in its first meeting held on 21-11-2023 decided that review of rule curves of Pong and Bhakra dam is required to be taken up by Reservoir Operations (RO) Directorate of CWC in consultation with BBMB. RO Directorate has requested for the following data from BBMB on 24-11-2023 which were received on 12-02-2024.

1. Daily Inflow (cusecs), Outflow (cusecs) and Level Data (ft) from 1984-2023.
2. Salient Features of Pong and Bhakra Dam (FRL, MWL, MDDL etc.)
3. Demand from both the dams raised by partner states and other .(2019-2023)
4. Elevation Capacity Table, Spillway Rating Table.
5. Exiting Rule Curves
6. Evaporation from both reservoirs from 2019-2023
7. Layout of both the Dams.

The 10 daily Evaporation data was received vide email dated 23-02-2023. Further, some discrepancies were observed in demand and inflow data pertaining to the Pong reservoir and communicated to BBMB vide email dated 28.03.2024. BBMB has clarified vide email dated 12-04-2024 that the demand data provided at Harike is met by Madhopur Beas link and waters of Sutlej also. RO Dte has sought the inflow data series of Madhopur Beas link and waters of Sutlej downstream of Ropar vide email dated 25-04-2024 which was provided vide BBMB email dated 15-05-2024.

The rule curves of Bhakra and Pong Dams have been prepared by Reservoir Operations Directorate of CWC in consultation with BBMB on the basis of the above data provided. A schematic diagram of the Bhakra /Pong reservoir system is given below.

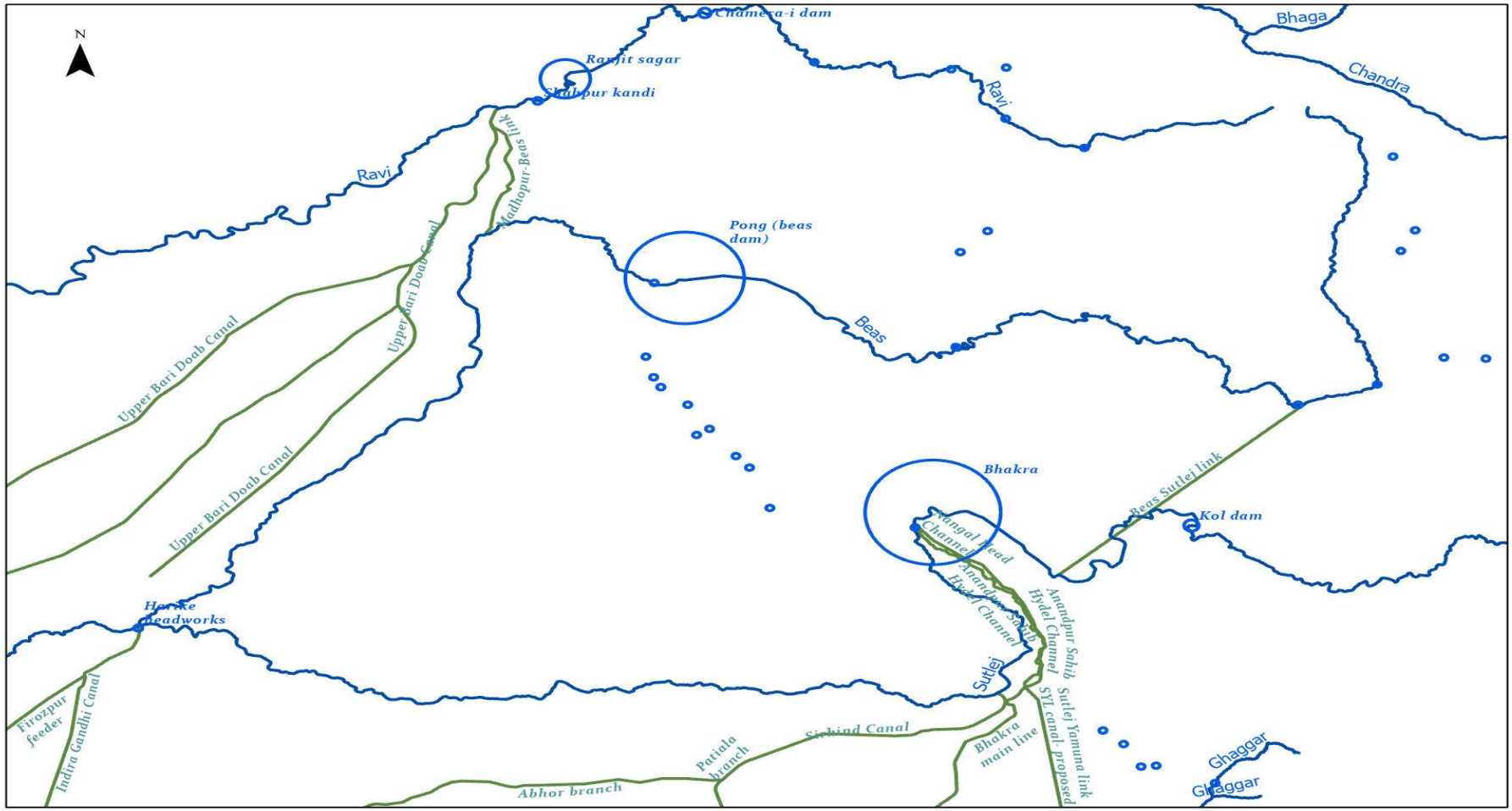

Fig 1: Bhakra and Pong Reservoir system

2 Overview of Bhakra Dam

Bhakra Dam is a concrete gravity dam across the Sutlej River and is near the border between Punjab and Himachal Pradesh in northern India. The dam, located at a gorge near the upstream Bhakra village in Bilaspur district of Himachal Pradesh, which is about 13 km upstream from Nangal township. It is Asia's second tallest at 225.55 m (740 ft) high next to the 261m Tehri Dam also in India. Its reservoir, known as the "Gobind Sagar", stores up to 9.34 billion cubic meters of water. The 90 km long reservoir created by the Bhakra Dam is spread over an area of 168.35 km2. In terms of storage of water, it is the second largest reservoir in India

Salient Features

Salient Features of Bhakra Dam are as follows:

Table 1: Levels:

	ft	m
Maximum Water Level (MWL)	1700	518.16
Full Reservoir Level (FRL)	1680	512.06
Spillway Crest Level	1646	501.70
Dead Storage Level (DL)	1462	445.61

Table 2: River Outlets and Flood control gates

No. of Outlets	16 in two tiers of each 8 at 1320 ft and 1420 ft
Maximum discharge per outlets at 1320 ft	6638 cusecs
Maximum discharge per outlets at 1420 ft	5656 cusecs
No. and Size of Control Gates	4 Nos, 50ft x 47.5ft
Max Design Discharge through Flood Control Gates	1,97,300 cusecs

3. Overview of Pong Dam

Pong reservoir has been constructed on the river Beas in the wet land of Shivalik hills of Kangra district of Himachal Pradesh, which has been named as Maharana Pratap Sagar. It is also known as Pong reservoir or Pong Dam. This dam was built in 1975 named in honor of Maharana Pratap, this reservoir or lake is a famous wildlife sanctuary and one of the 25 international wetland sites declared by Ramsar Sammel in India. The reservoir stretches to an area of 24,529 hectares (60,610 acres), and part of the lakes is 15,662 hectares (38,700 acres).

Salient Features

Salient features of Pong Dam are as follows:

Table 3: Levels

	ft	m
Maximum Water Level (MWL)	1421	433.405
Full Reservoir Level (FRL)	1410	430.05
Crest Level	1365	416.325
Dead Storage Level (DL)	1260	384.30

Table 4: Flood control gates

Spillway Radial Gates: -	6 number of 47.5 ft x 40.5 ft
Design Discharge at RL	4,37,000 cs

After the floods of 1988 it was decided in 138th and 139th meetings of Bhakra Beas Management Board held on 19-07-1990 and 28-09-1990 that meetings that maximum levels at Bhakra and Pong should be kept as 1680 ft and 1390 ft respectively for storage purposes. It was decided that in case levels are allowed to rise a little higher than these values for the purpose of flood routing / absorption and avoid synchronization of releases with those of rivulets downstream of the dams, the levels would be brought down as soon as the conditions downstream of reservoirs permit.

Based on above decision, the operation rule for Pong have been prepared restricting its **FRL to 1390 ft.**

4. Derivation of Rule Curves for Different Purposes

- Upper Rule Level

  All the rule curves are derived for scarcity situations so as to foresee the critical conditions in the reservoir and to timely regulate the supply of water for various purposes. The uppermost rule levels are calculated for the case when there is sufficient inflow in the reservoir and it is possible to spill some water without affecting its performance. Though it is most desirable to fill the reservoir up to FRL, sometimes, it is required to spill water from the reservoir to keep up the downstream channel and to avoid encroachment in the river bed. The conditions which are presumed for deriving upper rule curve are:

  i) Reservoir level is kept at FRL after the end of monsoon period (September end to May end).
  ii) 50% reliable inflow is entering the reservoir. 50% dependable synthetic inflow has been used for preparation of operation rules rather than the absolute tend daily inflows of 50% dependable year.
  iii) All conservation demands from the reservoir are being met in full.

  Backward calculations are carried out starting from the FRL at the end of monsoon up to start of June and restricting it upto crest level. Evaporation loss is considered at normal monthly rate over the surface area of the reservoir corresponding to a particular elevation. The following formula is used:

  $$Storage_{begin} = Storage_{end} - Inflow + Demand + Evaporation + Spill$$

- Conservation Rule Level

  Rule levels for other conservation demands like irrigation, hydroelectric power etc. is calculated assuming the following conditions:

  i) Reservoir level reaches to dead storage level by the end of water year (May end).
  ii) 75% reliable inflow is entering the reservoir. 75% dependable synthetic inflow has been used for preparation of operation rules rather than the absolute tend daily inflows of 50% dependable year.
  iii) The demand under consideration and other higher priority demands are met in full.

  Backward computations are made starting from the end of May and evaporation loss is considered at normal monthly rate over the surface area of the reservoir corresponding to a particular elevation. The following formula is used:

  $$Storage_{begin} = Storage_{end} - Inflow + Demand + Evaporation + Spill$$

  Thus effort is made to find such a level that if the reservoir level is above this level, then demand under consideration and higher priority demands can be satisfied in full and there is no need to curtail the demands. If the inflow to the reservoir is so less that this level cannot be maintained, then supply for meeting demands need to be curtailed.

5. OPERATION RULE OF BHAKRA RESERVOIR

5.1 Data processing, analysis, and validation

The data received from BBMB was processed, analysed and validation checks were applied on a few general parameters. Firstly, the reservoir levels were plotted on a chart to visualize the possible typological anomalies as shown in Fig 2. After removing those anomalies, the consistency of inflow data series as shown in Fig 3 was checked on the basis of reservoir levels provided for the entire period of time series. For checking this inconsistency, BBMB was requested to provide the reservoir storage data but due to unavailability of such historical data, the respective reservoirs storage were derived corresponding to the provided reservoir level data using the latest elevation capacity table provide by BBMB .

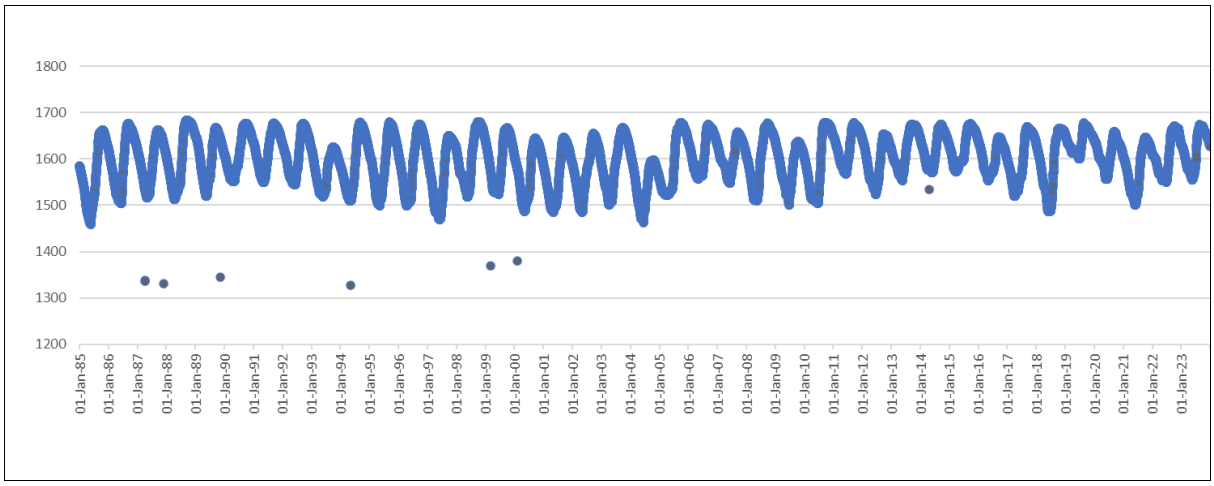

Fig 2: Anomalies in the reservoir level Bhakra

After fixing the above anomalies in the reservoir level following inconsistencies remained in the inflow data of Bhakra Dam which could not be rectified without the availability of actual storage data recorded at the dam site.

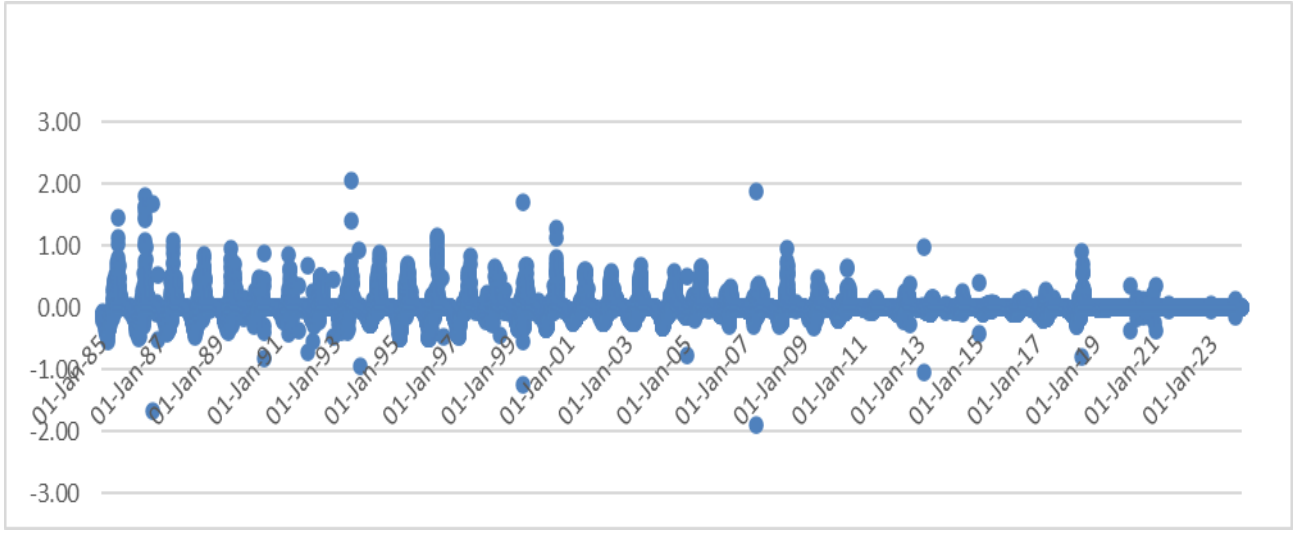

Fig 3: Anomalies in the inflow data of Bhakra

5.2 Computation of Inflow data at ten-daily time interval (TMC ft.) from 1984-2023

The daily inflow data received in cusecs has been converted into TMC at 10 daily time interval from 1984-2023 (as attached in Annexure –I) and arranged in descending order to find out the 75% and 50% dependable inflows and further the respective synthetic inflows were computed for rule level computation.

10 daily inflows from the year 1984-85 to 2022-23 are plotted as shown in Fig: 4 and 75% and 50% dependable synthetic inflows and total demand from Bhakra are plotted in Fig: 5.

5.3 Elevation Capacity

The elevation capacity table provided by BBMB was in cusecs-days which has been converted into TMC ft as shown in table 6 and plotted in Fig 6.

5.4 Rule Levels

The Upper Rule level and Conservation Rule Level computed is shown in Fig: 7. The 10 daily time step values are shown in Table 7. The upper rule is computed for 50% dependable synthetic inflow and level is kept at FRL from 20th September. i.e the end of monsoon period on the basis of inflection point between inflow and demand. The conservation rule level is derived for 75% dependable synthetic inflow.
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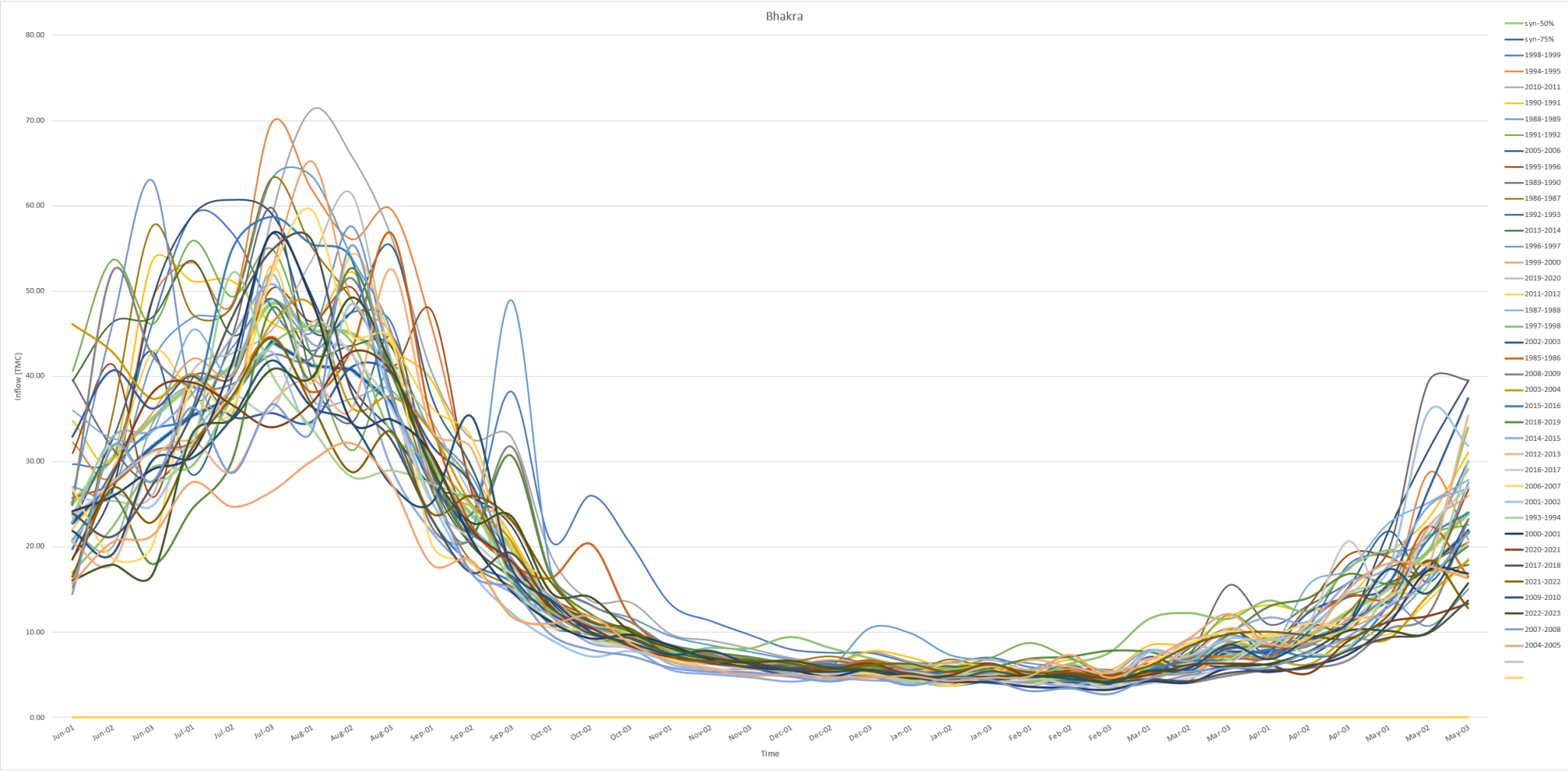


Fig 4: Ten-daily Inflow data line chart (in TMC ft.)

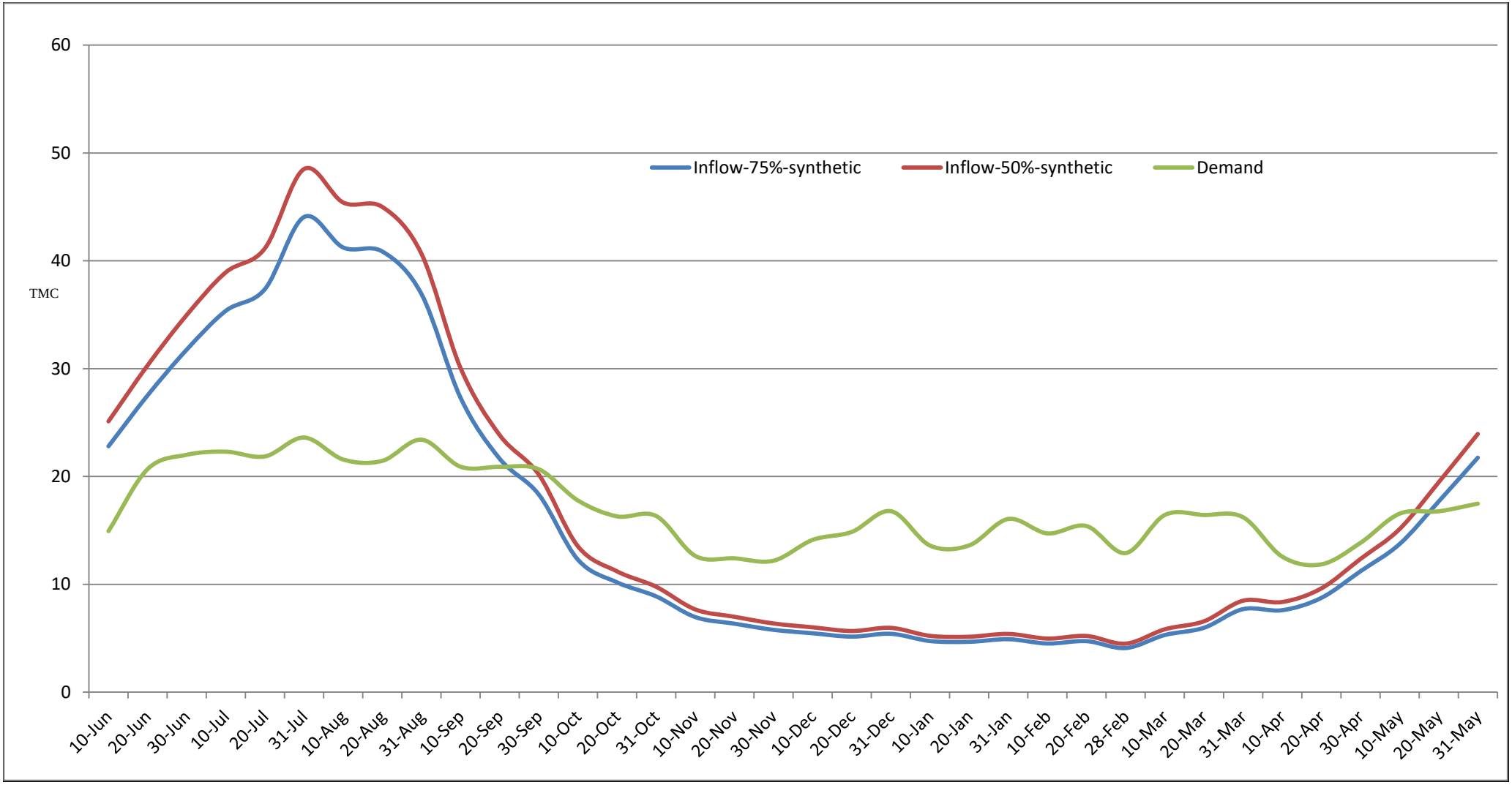


Fig 5: Synthetic Inflow 75% and 50% dependable and Demand (in TMC-Ft.)

5.4 Irrigation Demand (TMC-Ft.)

The Demand from Bhakra was provided in cusec days from 2019-2023 which was further converted to TMC on 10 daily time steps as given in Table 5. The total average demand is 608.3 TMC.

Table 5: Total demand (TMC) from Bhakra as per timestep wise made in last five years.

TIME STEP	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	AVG
JUN-01		18.7	14.7	15.0	13.9	11.4	14.7
JUN-02		21.3	20.8	20.0	21.2	19.1	20.5
JUN-03		21.7	22.9	20.3	21.5	22.7	21.8
JUL-02		21.0	22.9	20.4	21.6	22.7	21.7
JUL-03		21.9	24.7	22.6	23.8	24.5	23.5
AUG-01		21.4	21.6	20.1	21.6	22.7	21.5
AUG-02		21.4	21.6	19.5	21.6	22.7	21.4
AUG-03		23.5	23.8	20.4	23.8	24.9	23.3
SEP-01		20.5	21.2	18.5	21.4	22.2	20.8
SEP-02		20.5	21.2	18.5	21.4	22.2	20.8
SEP-03		19.9	21.1	18.1	21.4	22.2	20.5
OCT-01		19.0	17.7	15.9	17.0	18.8	17.7
OCT-02		17.9	14.8	13.9	15.7	18.8	16.2
OCT-03		18.7	13.1	14.3	17.2	17.8	16.2
NOV-01		13.4	11.4	11.4	13.5	13.2	12.6
NOV-02		13.4	13.8	11.4	10.0	13.1	12.3
NOV-03		13.3	12.2	11.4	10.5	13.3	12.1
DEC-01		14.9	12.6	13.9	14.9	13.9	14.1
DEC-02		14.9	14.5	13.9	15.8	14.9	14.8
DEC-03		15.2	17.0	15.3	17.8	18.3	16.7
JAN-01	16.2	14.4	14.5	13.8	8.8		13.5
JAN-02	16.2	14.5	13.5	14.8	8.8		13.6
JAN-03	17.8	16.1	14.7	16.3	15.1		16.0
FEB-01	15.9	15.5	12.2	13.9	15.8		14.7
FEB-02	15.9	16.6	13.5	14.4	16.2		15.3
FEB-03	13.1	15.9	10.8	11.5	13.0		12.9
MAR-01	15.9	18.3	15.2	15.7	16.6		16.3
MAR-02	15.9	18.3	15.2	15.7	16.6		16.3
MAR-03	17.5	13.0	14.5	17.2	18.3		16.1
APR-01	14.8	12.2	11.5	13.9	9.8		12.4
APR-02	12.2	12.2	6.7	13.9	13.6		11.7
APR-03	14.2	12.9	11.2	15.5	14.9		13.7
MAY-01	17.2	15.1	14.4	18.4	16.8		16.4
MAY-02	17.2	15.1	15.8	18.4	16.4		16.6
MAY-03	19.0	15.6	15.8	20.3	15.9		17.3
TOTAL							608.3

Table 6: Elevation Capacity table

ELEVATION (FT.)	CAPACITY IN TMC-FT									
	0	1	2	3	4	5	6	7	8	9
1400	28.55	28.85	29.14	29.44	29.74	30.04	30.34	30.64	30.93	31.23
1410	31.53	31.83	32.13	32.43	32.72	33.02	33.32	33.62	33.92	34.21
1420	34.51	34.84	35.17	35.50	35.82	36.15	36.48	36.81	37.14	37.46
1430	37.79	38.12	38.45	38.78	39.10	39.43	39.76	40.09	40.42	40.74
1440	41.07	41.43	41.79	42.15	42.50	42.86	43.22	43.58	43.93	44.29
1450	44.65	45.01	45.37	45.72	46.08	46.44	46.80	47.16	47.51	47.87
1460	48.23	48.62	49.00	49.39	49.78	50.16	50.55	50.94	51.32	51.71
1470	52.10	52.48	52.87	53.26	53.64	54.03	54.42	54.80	55.19	55.58
1480	55.96	56.39	56.82	57.24	57.67	58.09	58.52	58.95	59.37	59.80
1490	60.22	60.65	61.08	61.50	61.93	62.35	62.78	63.21	63.63	64.06
1500	64.48	64.94	65.40	65.86	66.31	66.77	67.23	67.69	68.14	68.60
1510	69.06	69.52	69.97	70.43	70.89	71.35	71.80	72.26	72.72	73.18
1520	73.64	74.12	74.61	75.10	75.59	76.08	76.57	77.06	77.55	78.04
1530	78.53	79.02	79.51	80.00	80.49	80.98	81.47	81.96	82.45	82.94
1540	83.43	84.06	84.69	85.32	85.95	86.58	87.20	87.83	88.46	89.09
1550	89.72	90.35	90.98	91.61	92.24	92.87	93.49	94.12	94.75	95.38
1560	96.01	96.83	97.65	98.47	99.29	100.11	100.93	101.74	102.56	103.38
1570	104.20	105.02	105.84	106.66	107.48	108.30	109.12	109.93	110.75	111.57
1580	112.39	113.41	114.42	115.44	116.46	117.47	118.49	119.51	120.52	121.54
1590	122.55	123.57	124.59	125.60	126.62	127.63	128.65	129.67	130.68	131.70
1600	132.71	133.92	135.12	136.32	137.53	138.73	139.93	141.14	142.34	143.54
1610	144.75	145.95	147.15	148.36	149.56	150.76	151.97	153.17	154.37	155.58
1620	156.78	158.15	159.53	160.91	162.28	163.66	165.03	166.41	167.78	169.16
1630	170.53	171.91	173.28	174.66	176.04	177.41	178.79	180.16	181.54	182.91
1640	184.29	185.83	187.37	188.91	190.45	191.99	193.53	195.07	196.61	198.15
1650	199.69	201.23	202.77	204.31	205.85	207.39	208.93	210.47	212.01	213.55
1660	215.09	216.77	218.45	220.13	221.81	223.49	225.17	226.85	228.53	230.21
1670	231.89	233.57	235.25	236.93	238.62	240.30	241.98	243.66	245.34	247.02
1680	248.70	250.52	252.34	254.15	255.97	257.79	259.61	261.43	263.25	265.07
1690	266.89	268.71	270.53	272.35	274.17	275.99	277.81	279.63	281.45	283.27
1700	285.09									

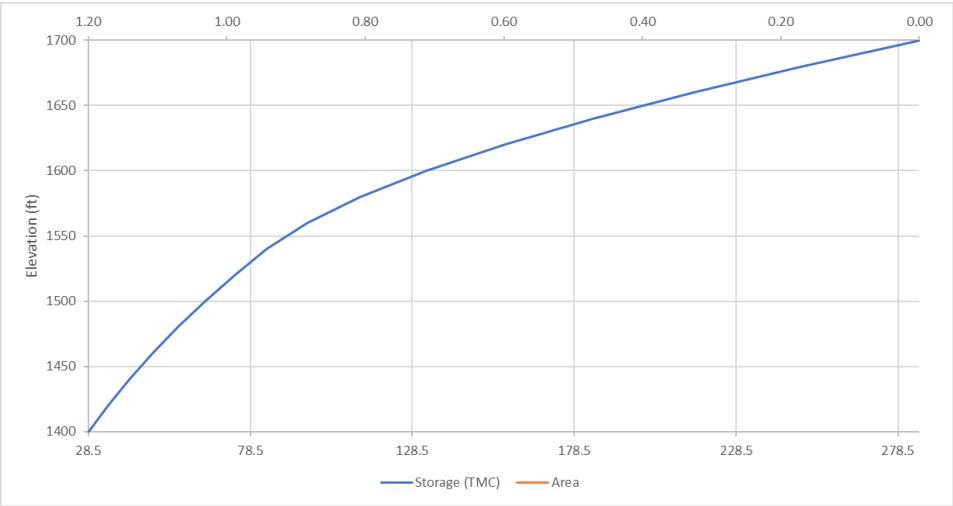


Fig 6: Elevation capacity chart Bhakra Dam

Table 7: Rule Levels (for conservation i.e. meeting the demands and for flood moderation)

DATE	INFLOW-75%-SYNTHETIC	INFLOW-50%-SYNTHETIC	EVL	DEMAND-IRRIG+EVL	DEMAND-IRRIG+HP+EVL	CONSERVATION-RULE-STORAGE	UPPER-RULE-STORAGE	CONSERVATION-RULE-LEVEL	UPPER-RULE-LEVEL
10-JUN	22.80	25.11	0.19	14.93	14.93	95.20	193.53	1558.70	1646.0
20-JUN	27.52	30.30	0.20	20.68	20.68	102.03	193.53	1567.35	1646.0
30-JUN	31.76	34.97	0.17	22.01	22.01	111.79	193.53	1579.26	1646.0
10-JUL	35.36	38.93	0.14	22.30	22.30	124.84	193.53	1592.25	1646.0
20-JUL	37.38	41.16	0.14	21.86	21.86	140.36	193.53	1606.36	1646.0
31-JUL	44.06	48.51	0.11	23.61	23.61	160.81	193.53	1622.93	1646.0
10-AUG	41.23	45.40	0.09	21.57	21.57	180.47	195.82	1637.22	1647.5
20-AUG	40.86	44.99	0.10	21.45	21.45	199.88	219.36	1650.12	1662.5
31-AUG	36.92	40.65	0.13	23.41	23.41	213.39	236.60	1658.89	1672.8
10-SEP	27.29	30.05	0.13	20.90	20.90	219.79	245.76	1662.79	1678.3
20-SEP	21.64	23.83	0.13	20.89	20.89	220.54	248.70	1663.24	1680.0
30-SEP	18.32	20.17	0.12	20.67	20.67	218.19	248.70	1661.84	1680.0
10-OCT	12.28	13.52	0.09	17.77	17.77	212.70	248.70	1658.45	1680.0
20-OCT	10.18	11.20	0.08	16.30	16.30	206.58	248.70	1654.47	1680.0
31-OCT	8.88	9.77	0.10	16.33	16.33	199.13	248.70	1649.64	1680.0
10-NOV	6.96	7.67	0.08	12.63	12.63	193.46	248.70	1645.96	1680.0
20-NOV	6.35	6.99	0.08	12.41	12.41	187.40	248.70	1642.02	1680.0
30-NOV	5.78	6.37	0.07	12.19	12.19	181.00	248.70	1637.61	1680.0
10-DEC	5.46	6.01	0.05	14.12	14.12	172.34	248.70	1631.32	1680.0
20-DEC	5.15	5.67	0.06	14.86	14.86	162.64	248.70	1624.26	1680.0
31-DEC	5.41	5.96	0.05	16.78	16.78	151.27	248.70	1615.42	1680.0
10-JAN	4.74	5.22	0.04	13.59	13.59	142.42	248.70	1608.07	1680.0
20-JAN	4.67	5.14	0.05	13.61	13.61	133.47	248.70	1600.63	1680.0
31-JAN	4.91	5.40	0.05	16.06	16.06	122.32	248.70	1589.77	1680.0
10-FEB	4.51	4.97	0.05	14.72	14.72	112.11	248.70	1579.65	1680.0
20-FEB	4.73	5.21	0.07	15.40	15.40	101.44	248.70	1566.63	1680.0
28-FEB	4.09	4.50	0.05	12.90	12.90	92.62	248.70	1554.62	1680.0
10-MAR	5.30	5.83	0.08	16.43	16.43	81.49	248.70	1536.04	1680.0
20-MAR	5.97	6.57	0.09	16.43	16.43	71.03	248.70	1514.30	1680.0
31-MAR	7.70	8.48	0.12	16.22	16.22	62.51	248.70	1495.38	1680.0
10-APR	7.60	8.36	0.12	12.57	12.57	57.54	248.70	1483.71	1680.0
20-APR	8.74	9.62	0.11	11.85	11.85	54.44	248.70	1476.05	1680.0
30-APR	11.21	12.35	0.11	13.84	13.84	51.81	248.70	1469.27	1680.0
10-MAY	13.73	15.12	0.16	16.55	16.55	49.00	248.70	1462.00	1680.0
20-MAY	17.68	19.46	0.18	16.77	16.77	49.00	248.70	1462.00	1680.0
31-MAY	21.74	23.94	0.16	17.48	17.48	49.00	248.70	1462.00	1680.0
TOTAL	578.91	637.40	3.75	612.06	612.06				

The conservation and upper rule levels are plotted in Figure-7

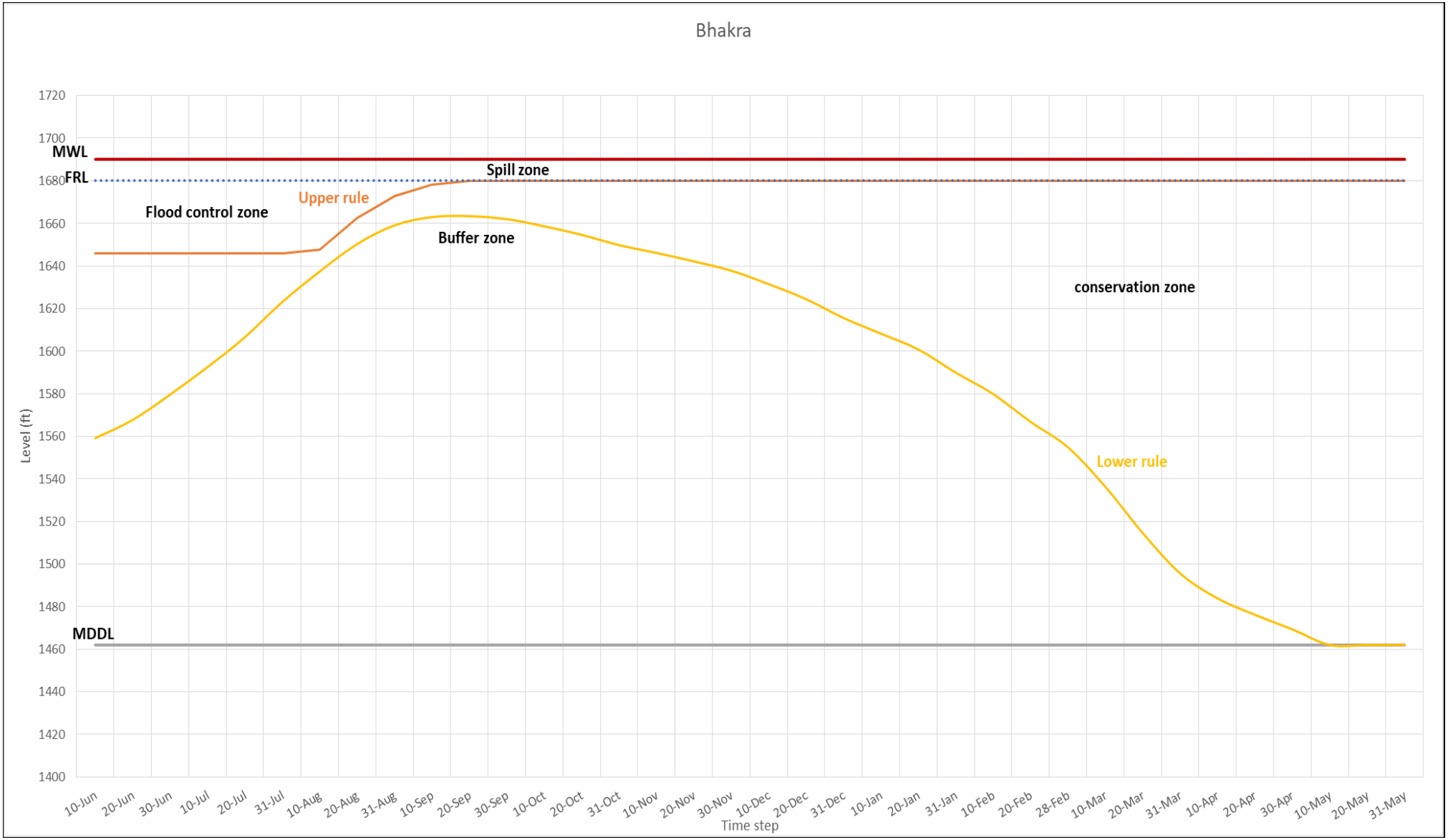
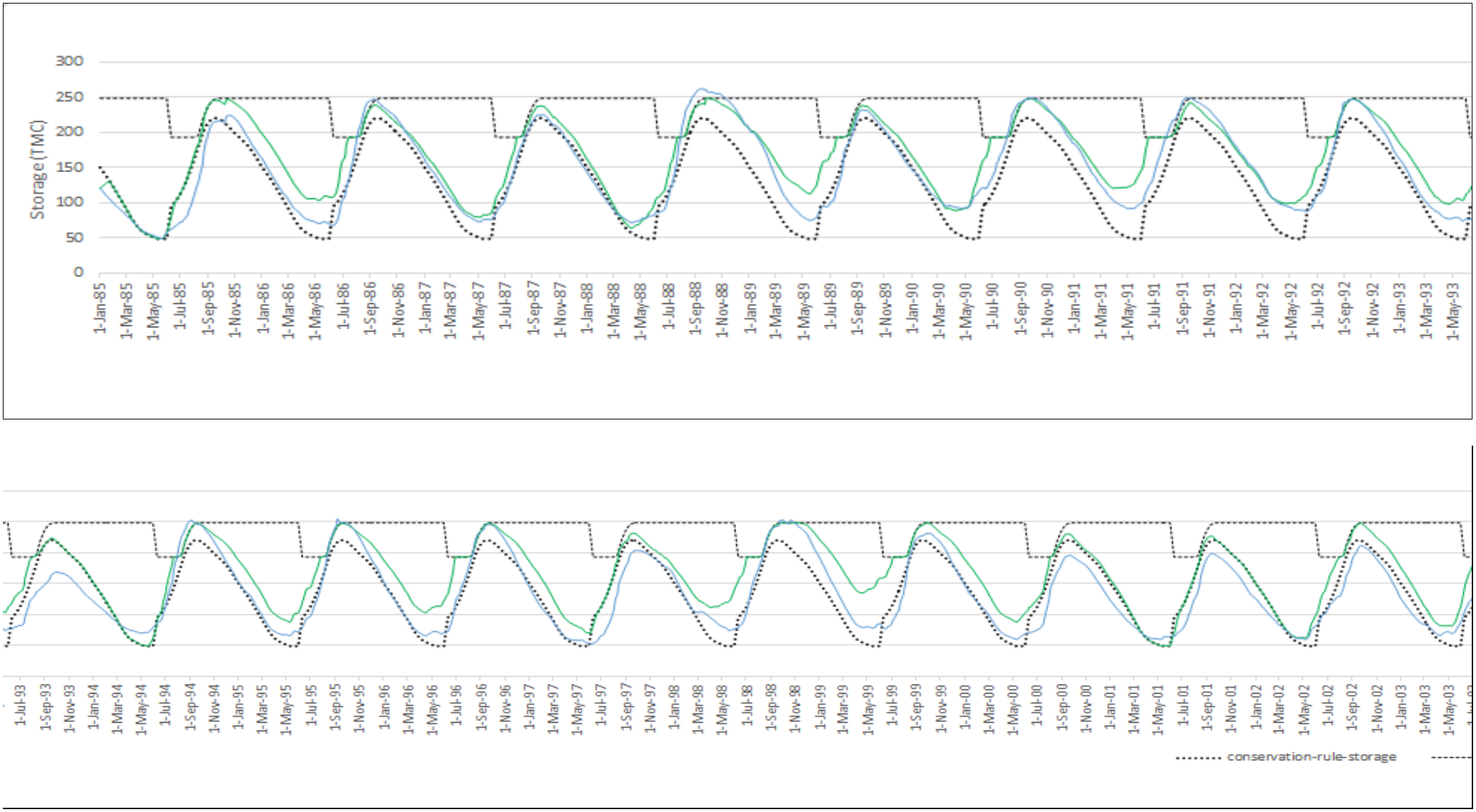


Fig 7: Rule Levels of Bhakra Dam

5.5 Hindcast simulation chart

The following Figures show the simulation chart on daily time steps. The green line shows the simulated storage if the reservoir is operated as per the rule curve whereas the blue line shows the actual storage derived from the daily reservoir level data provided by BBMB.



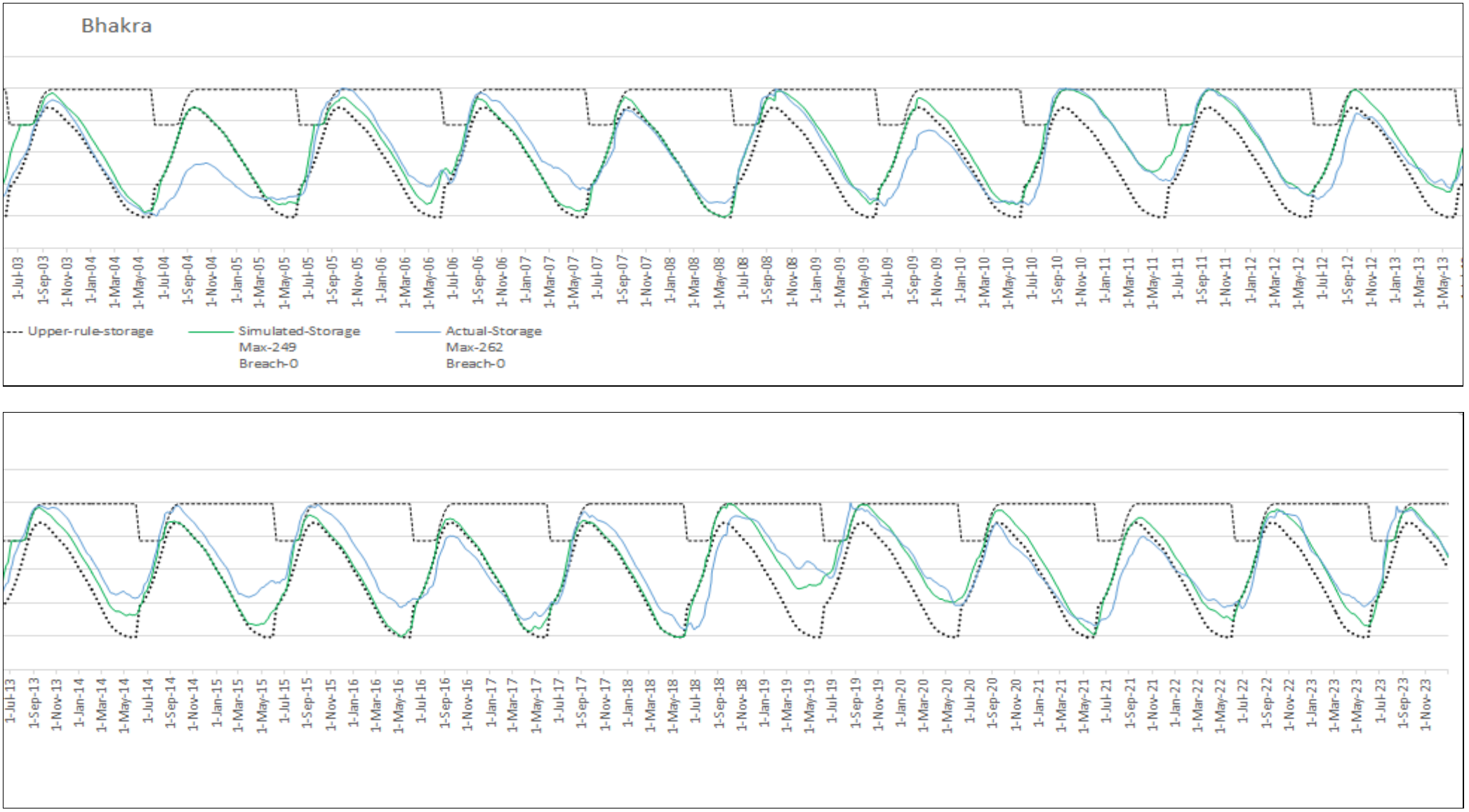


Fig 8: Conservation Rule storage, Upper Rule Storage , Simulated Storage and Actual Storage

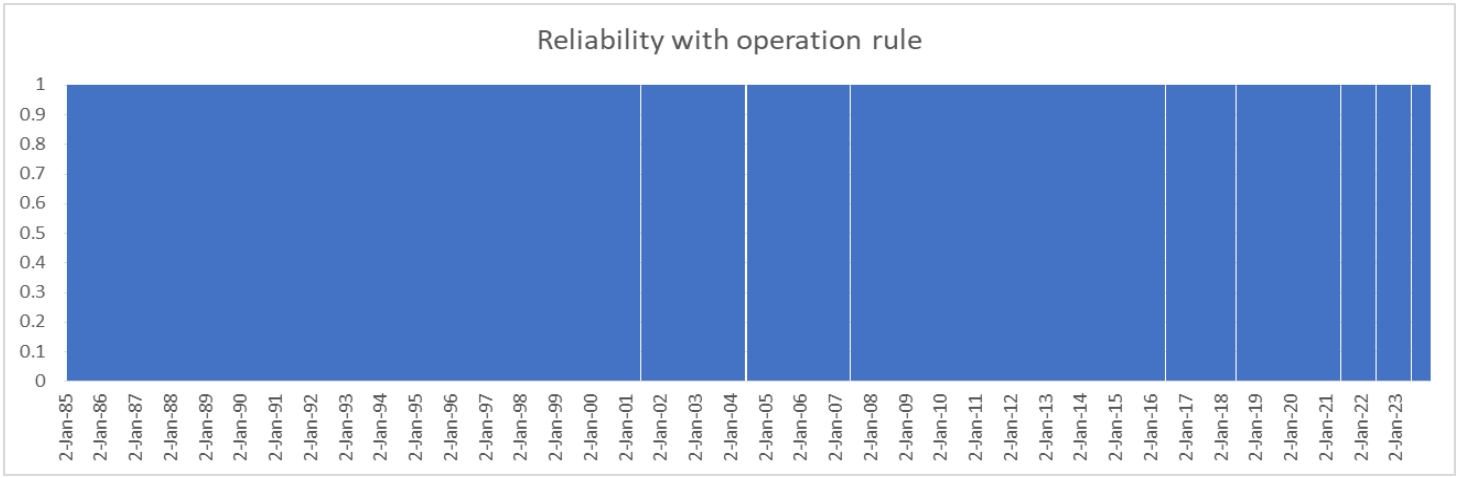
Table 8: Performance indices for conservation purposes:

Name of Dam/ Reservoir	Performance with operation rule		Performance without operation rule	
	Reliability (% days standard demand is fully met)	Vulnerability (avg. curtailment in demand when demand is not fully met)	Reliability (% days demand is fully met)	Vulnerability (avg. curtailment in demand when demand is not fully met)
Bhakra	98%	0.67 TMC	50%	0.33 TMC

Table 9: Performance indices for flood moderation purpose:

Name of Dam/ Reservoir	Performance with operation rule			Performance without operation rule	
	MRL/MWL breach events	Spill breach events	Observed maximum outflow (from all the outlets combined)	MRL/MWL breach events when limiting the spill to spillway capacity	Simulated maximum outflow (from all the outlets combined)
Bhakra	0	0	31-Jul-89 1,18,221cusec	0	25-Sep-88 1,23,767cusec

Following figures represents the performance (in terms of reliability) with and without operation Rule:
1 represents the demand is fully met on a particular day and 0 represents the demand is not met and needs to be curtailed.



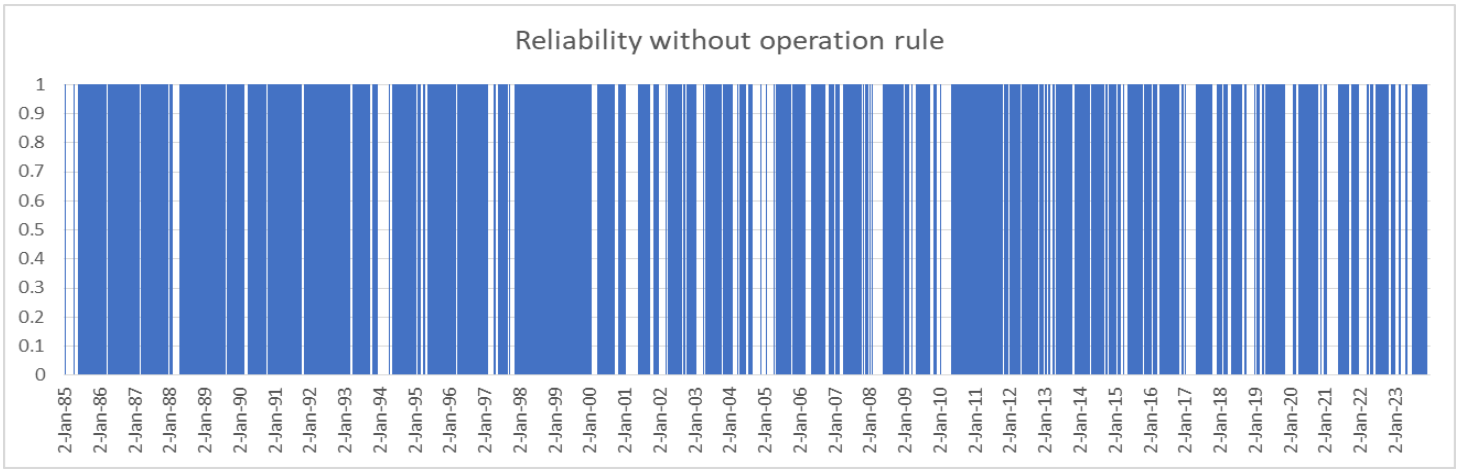


Fig 9: Reliability with and without Operation Rule

6. OPERATION RULE OF PONG RESERVOIR

6.1 Data processing, analysis, and validation

The data received from BBMB was processed, analysed and validation checks were applied on a few general parameters. Firstly, the reservoir levels were plotted on a chart to visualize the possible typological anomalies as shown in Fig 10. After removing those anomalies, the consistency of inflow data series as shown in Fig 11 was checked on the basis of reservoir levels provided for the entire period of time series. For checking this inconsistency, BBMB was requested to provide the reservoir storage data but due to unavailability of such historical data, the respective reservoirs storage were derived corresponding to the provided reservoir level data using the latest elevation capacity table provide by BBMB.

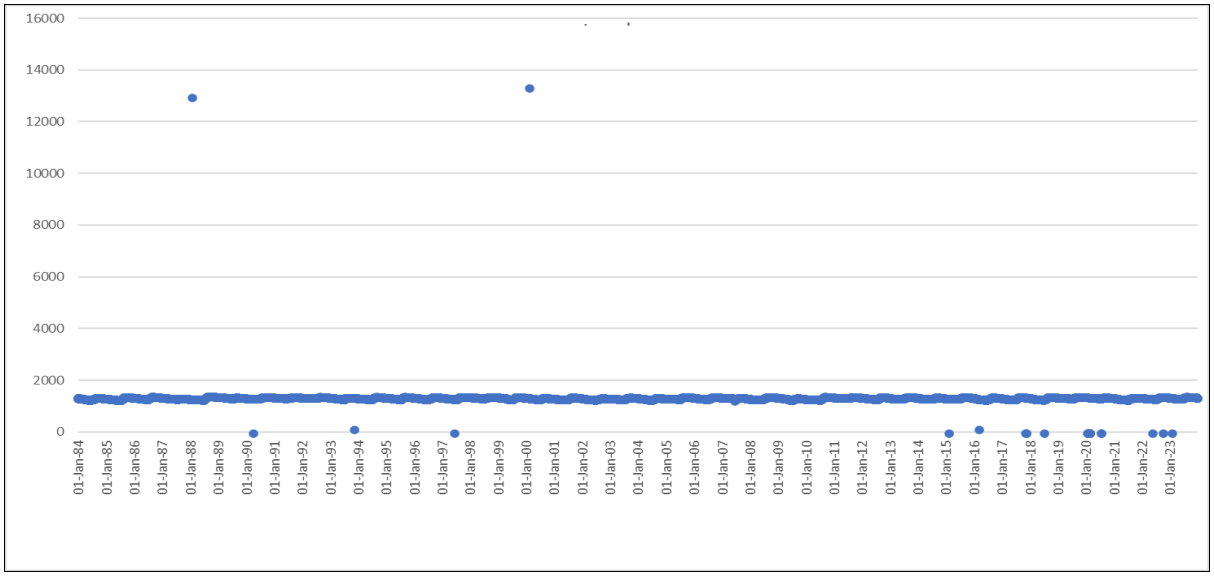


Fig 10: Anomalies in the reservoir level of Pong

After fixing the above anomalies in the reservoir level following inconsistencies remained in the inflow data of Pong Dam which could not be rectified without the availability of actual storage data recorded at the dam site or data of any nearby upstream site which could corroborate the existing data.

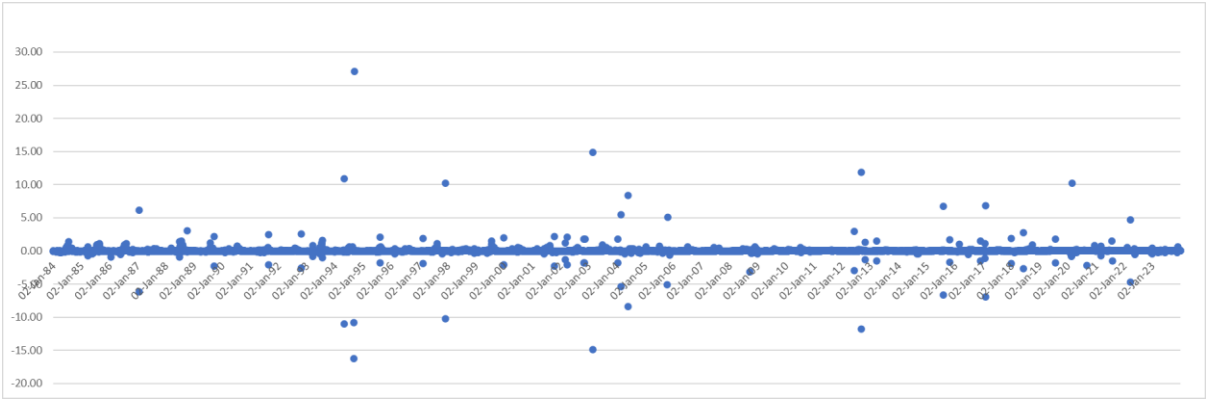


Fig 11: Anomalies in the inflow data of Pong dam

6.2 Computation of Inflow data at ten-daily time interval (in TMC ft.) from 1984-2023

The daily inflow data received in cusecs has been converted into TMC at 10 daily time interval from 1984-2023 (as attached in Annexure –II) and arranged in descending order to find out the 75% and 50% dependable inflows and further the respective synthetic inflows were computed for rule level computation.

10 daily inflows from the year 1984-85 to 2022-23 are plotted as shown in Fig: 12 and 75% and 50% dependable synthetic inflows and total demand from Pong are plotted in Fig: 13.

6.3 Elevation Capacity

The elevation capacity table provided by BBMB was in cusecs-days which has been converted into TMC ft as shown in table 11 and plotted in Fig 14.

6.4 Rule Levels

The Upper Rule level and Conservation Rule Level computed is shown in Fig: 15. The 10 daily time step values are shown in Table 12. The upper rule is computed for 50% dependable synthetic inflow and level is kept at FRL from 20th September. i.e the end of monsoon period and the conservation rule level is derived for 75% dependable synthetic inflow.

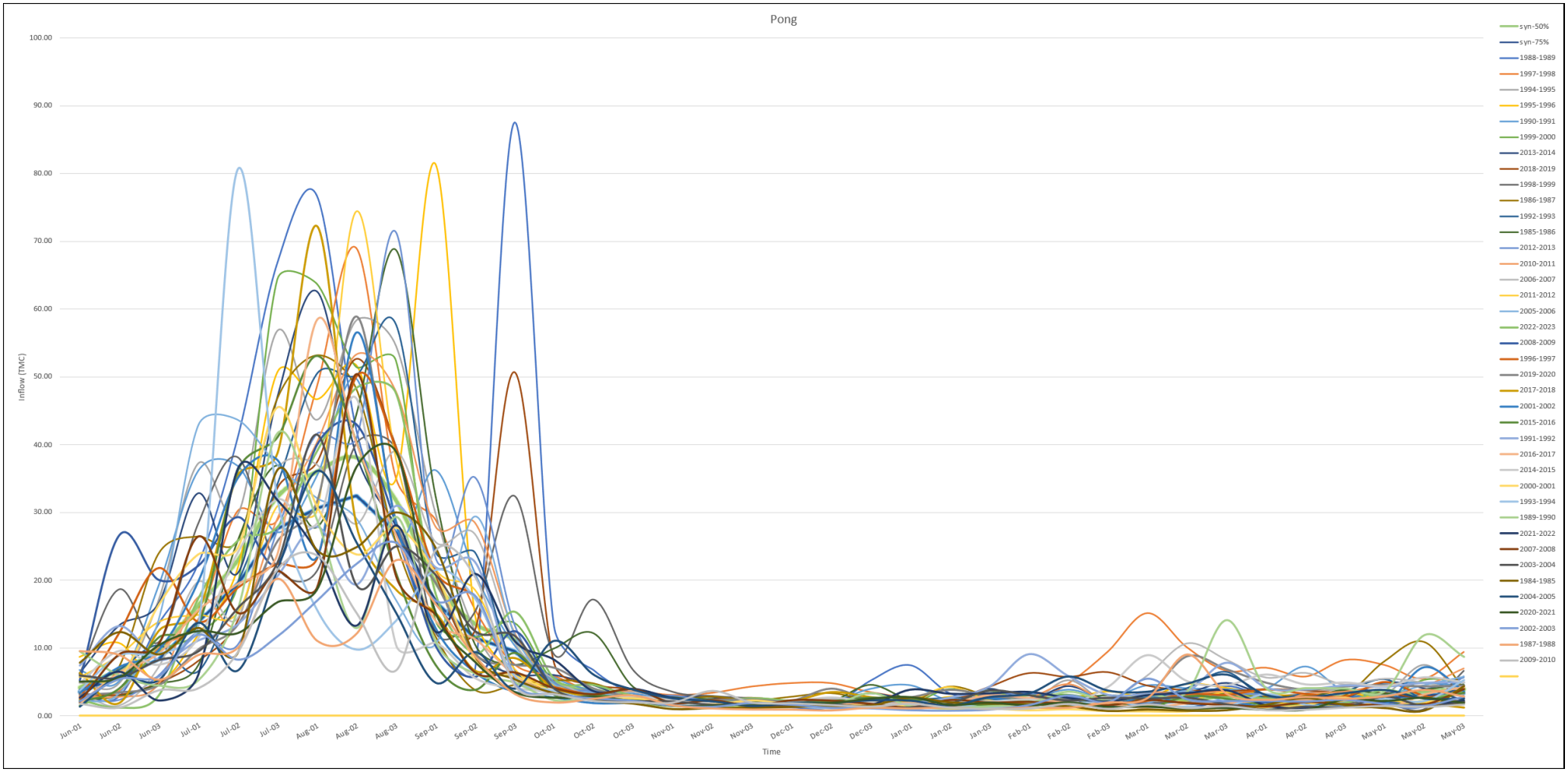


Fig 12 : Ten-daily Inflow data line chart (in TMC ft.)

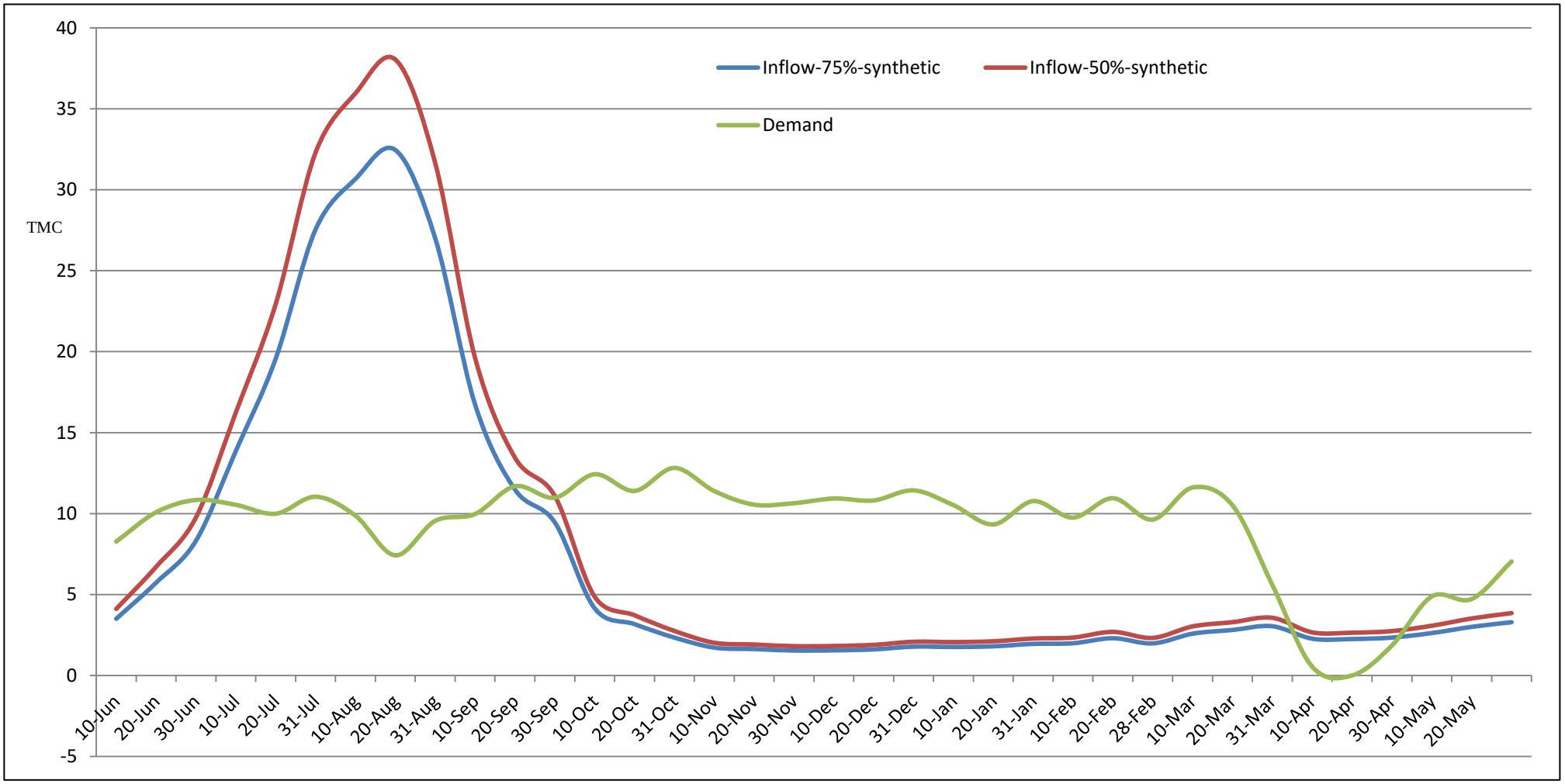


Fig 13: Synthetic Inflow 75% and 50% Dependable and Demand (TMC

6.5 Irrigation Demand (in TMC ft.)

The demand at Harike, raised by partner States is not met only through pong Dam rather diversion from river Ravi to Beas through Madhopur Beas link and through water released from downstream Ropar in satluj River reaching at upstream Harike is also considered. Net Average Demand to be met by Pong is 324.40 TMC. Net Demand to be met by pong is calculated as below:

> Net demand from Pong = Average Demand from Harike (2019-2023) – (Average Flow in M.B. Link (1984-2023)) – (Average Flow in the satluj D/S of Ropar (1984-2023))

Table 10: Net demand to be met by Pong Dam in TMC

Time-step	Demand from Harike							Averge contribution of Ravi Beas link at Harike	Averge contribution of Sutlej at Harike	Demand met from Pong
	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24	Average Demand met from Harike			
Jun-01		17.75	18.61	13.24	19.65	12.48	16.35	4.14	4.22	7.99
Jun-02		20.95	22.07	13.64	20.52	16.63	18.76	4.07	4.90	9.79
Jun-03		21.47	22.07	16.63	21.38	17.49	19.81	4.25	4.96	10.59
Jul-01		22.33	22.07	17.25	20.34	20.56	20.51	3.87	6.31	10.34
Jul-02		22.07	22.07	18.10	20.34	19.95	20.51	3.86	6.85	9.80
Jul-03		23.61	24.28	21.14	22.38	22.61	22.80	4.45	7.49	10.87
Aug-01		22.07	21.21	18.36	20.34	22.45	20.89	3.84	7.33	9.71
Aug-02		22.07	21.21	17.60	20.34	22.43	20.73	3.79	9.67	7.27
Aug-03		24.28	23.33	18.10	22.38	24.71	22.56	3.50	9.72	9.34
Sep-01		21.03	21.21	16.45	21.16	22.16	20.40	2.94	7.71	9.75
Sep-02		20.96	21.21	16.45	21.16	22.16	20.39	2.45	6.45	11.49
Sep-03		20.34	21.19	15.12	21.16	22.16	19.99	1.95	7.26	10.79
Oct-01		18.27	18.40	14.08	18.53	18.70	17.60	1.99	3.33	12.27
Oct-02		16.32	17.88	13.39	17.49	17.23	16.46	1.87	3.33	11.26
Oct-03		17.53	17.34	14.95	18.55	18.39	17.35	1.82	2.87	12.66
Nov-01		15.68	13.86	14.12	15.85	15.59	15.02	1.98	1.78	11.27
Nov-02		14.04	13.21	13.43	14.29	15.42	14.08	2.07	1.58	10.43
Nov-03		14.04	12.57	13.43	14.29	15.16	13.90	1.81	1.55	10.53
Dec-01		15.33	13.43	10.06	14.38	16.20	13.88	1.71	1.33	10.84
Dec-02		13.20	13.43	10.88	15.85	17.15	14.10	1.80	1.58	10.72
Dec-03		14.58	14.77	12.87	17.91	17.79	15.59	2.09	2.15	11.34
Jan-01	13.43	14.81	14.65	14.38	14.64		14.38	1.99	1.94	10.45
Jan-02	13.75	14.86	14.38	9.02	14.23		13.25	2.01	1.98	9.26
Jan-03	16.96	14.48	15.82	9.45	15.23		14.39	1.79	1.91	10.69
Feb-01	13.84	14.12	12.31	11.98	12.74		13.00	1.49	1.83	9.67
Feb-02	13.52	16.84	11.66	13.86	16.02		14.38	1.73	1.80	10.85
Feb-03	10.47	17.18	10.82	11.51	13.16		12.63	1.72	1.35	9.55
Mar-01	15.79	18.92	12.05	14.94	16.28		15.60	2.39	1.71	11.50
Mar-02	15.63	18.83	9.80	13.01	15.94		14.64	2.80	1.46	10.39
Mar-03	9.07	15.62	9.97	7.17	8.21		10.01	3.17	1.42	5.42
Apr-01	3.63	9.33	4.82	5.60	2.16		5.11	3.20	1.55	0.36
Apr-02	1.90	9.02	3.46	6.40	5.40		5.24	3.44	2.15	0

Time-step	Demand from Harike						Average Demand met from Harike	Averge contribution of Ravi Beas link at Harike	Averge contribution of Sutlej at Harike	Demand met from Pong
	2018-19	2019-20	2020-21	2021-22	2022-23	2023-24				
Apr-03	8.54	14.55	3.71	5.74	6.57		7.82	4.17	1.96	1.69
May-01	17.66	17.07	5.53	9.34	6.87		11.29	4.81	1.85	4.64
May-02	17.66	16.99	5.67	11.36	7.39		11.81	4.92	2.44	4.45
May-03	19.43	19.05	12.48	17.15	8.13		15.25	5.14	3.32	6.79
Total		629.61	542.54	480.20	561.28		560.47	105.04	131.03	324.40

Table 11: Elevation Capacity table

Resevoir Elevation (In-feet)	Capacity in TMC-FT									
	0	1	2	3	4	5	6	7	8	9
1260	35.94	36.56	37.18	37.80	38.42	39.04	39.66	40.28	40.90	41.52
1270	42.14	42.77	43.40	44.03	44.66	45.29	45.92	46.55	47.18	47.81
1280	48.44	49.36	50.27	51.18	52.09	53.00	53.91	54.82	55.73	56.64
1290	57.55	58.60	59.65	60.69	61.74	62.78	63.83	64.88	65.92	66.97
1300	68.01	69.23	70.45	71.66	72.88	74.09	75.31	76.52	77.74	78.96
1310	80.17	81.64	83.10	84.57	86.03	87.50	88.96	90.43	91.89	93.36
1320	94.83	96.40	97.98	99.55	101.13	102.70	104.28	105.85	107.43	109.00
1330	110.58	112.39	114.20	116.01	117.82	119.63	121.44	123.25	125.06	126.87
1340	128.68	130.58	132.48	134.38	136.28	138.17	140.07	141.97	143.87	145.76
1350	147.66	149.72	151.77	153.82	155.87	157.92	159.98	162.03	164.08	166.13
1360	168.19	170.43	172.66	174.90	177.14	179.38	181.62	183.86	186.10	188.34
1370	190.58	192.95	195.31	197.68	200.04	202.41	204.77	207.14	209.50	211.87
1380	214.24	216.79	219.34	221.89	224.44	227.00	229.55	232.10	234.65	237.20
1390	239.76	242.47	245.18	247.89	250.60	253.31	256.03	258.74	261.45	264.16
1400	266.87	269.71	272.55	275.38	278.22	281.05	283.89	286.73	289.56	292.40
1410	295.24									

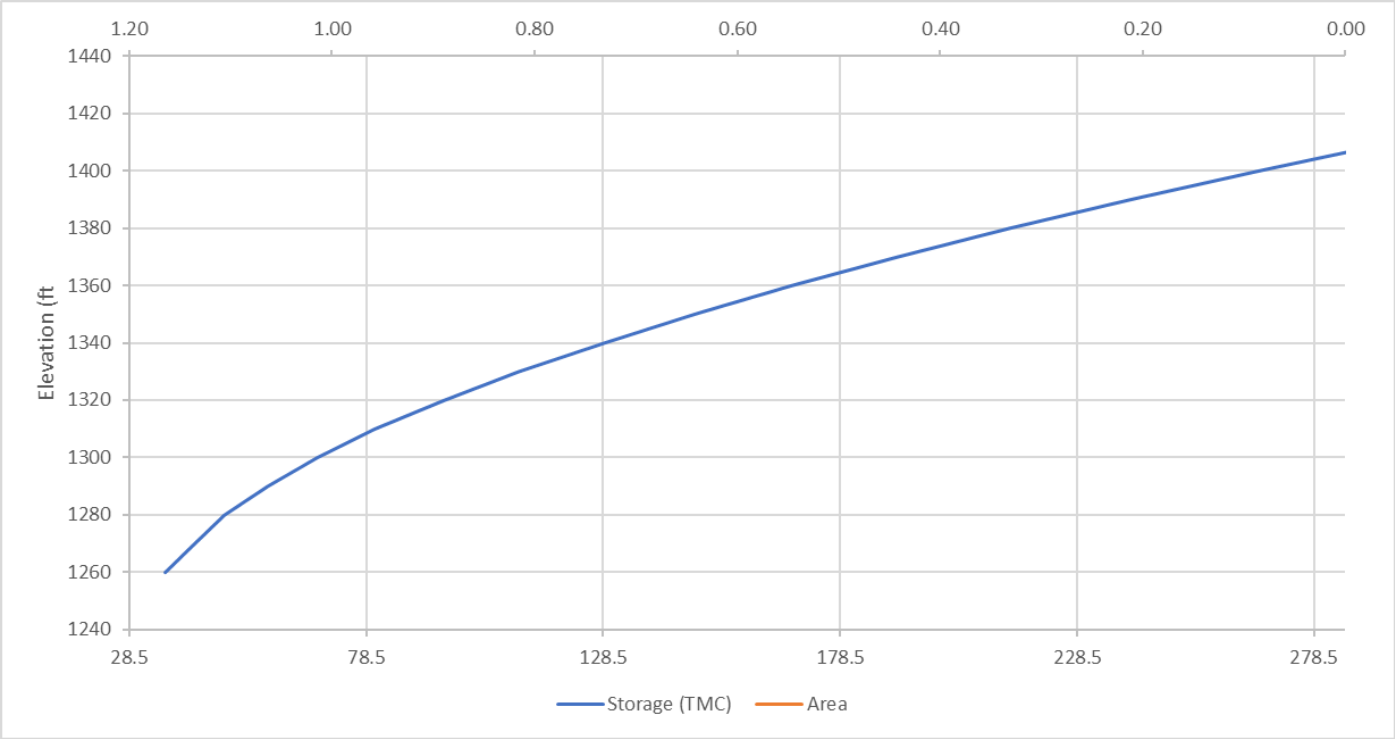
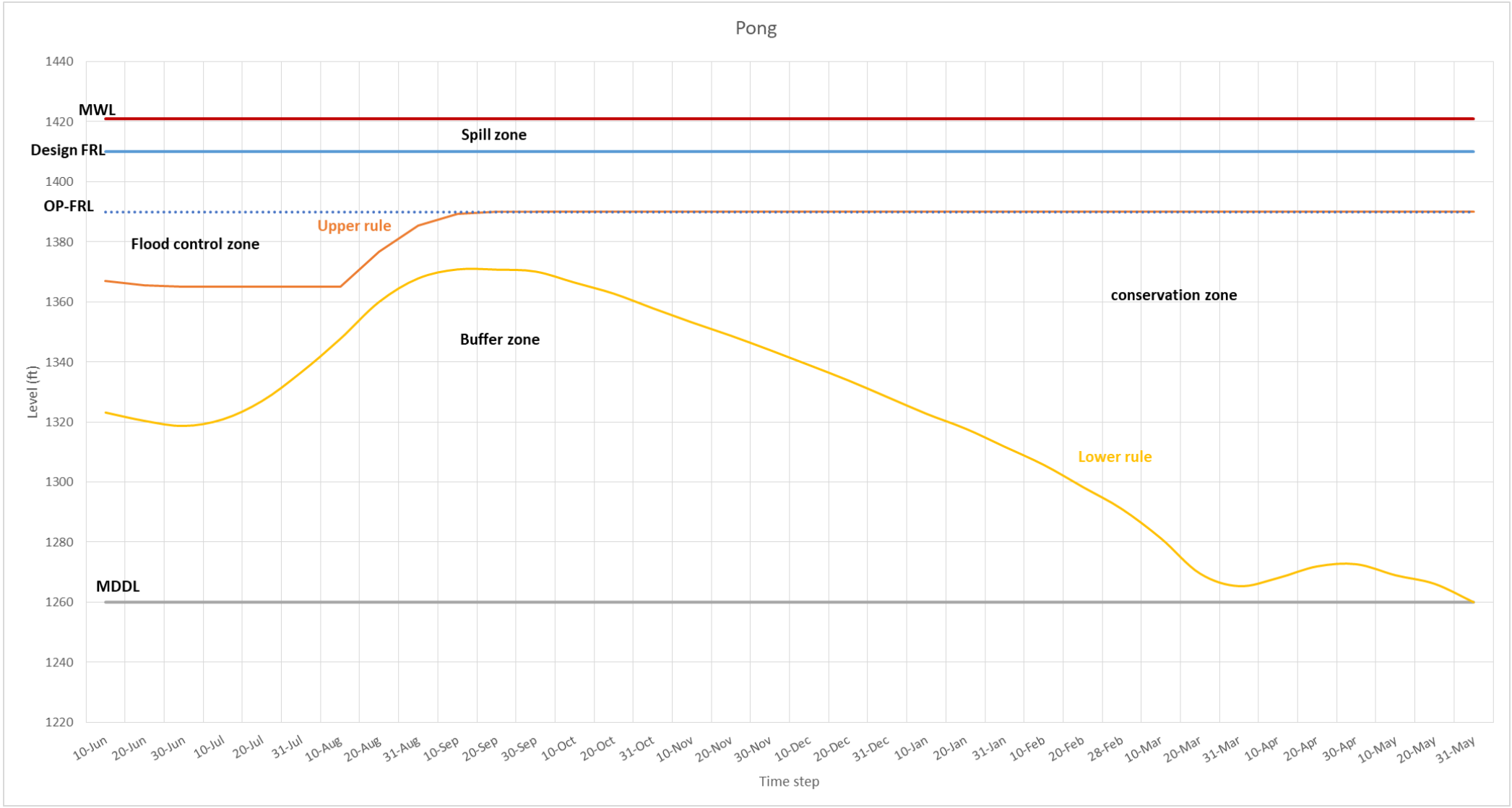


Fig 14: Elevation capacity chart Pong Dam

Table 12: Rule Levels (for conservation i.e. meeting the demands and for flood moderation)

DATE	INFLOW-75%-SYNTHETIC	INFLOW-50%-SYNTHETIC	EVL	DEMAND-IRRIG+EVL	DEMAND-IRRIG+HP+EVL	CONSERVATION-RULE-STORAGE	UPPER-RULE-STORAGE	CONSERVATION-RULE-LEVEL	UPPER-RULE-LEVEL
10-JUN	3.50	4.11	0.27	8.27	8.27	99.47	183.84	1322.9	1367.0
20-JUN	5.73	6.71	0.30	10.08	10.08	95.11	180.47	1320.2	1365.5
30-JUN	8.32	9.76	0.25	10.84	10.84	92.59	179.38	1318.5	1365.0
10-JUL	13.87	16.25	0.21	10.54	10.54	95.92	179.38	1320.7	1365.0
20-JUL	19.57	22.94	0.20	9.99	9.99	105.49	179.38	1326.8	1365.0
31-JUL	27.55	32.30	0.17	11.04	11.04	122.00	179.38	1336.3	1365.0
10-AUG	30.67	35.96	0.16	9.87	9.87	142.81	179.38	1347.4	1365.0
20-AUG	32.46	38.05	0.15	7.42	7.42	167.85	206.06	1359.8	1376.5
31-AUG	27.02	31.67	0.21	9.55	9.55	185.31	228.20	1367.6	1385.5
10-SEP	16.75	19.63	0.21	9.97	9.97	192.09	237.89	1370.6	1389.3
20-SEP	11.49	13.46	0.20	11.69	11.69	191.89	239.68	1370.6	1390.0
30-SEP	9.46	11.09	0.19	10.98	10.98	190.37	239.80	1369.9	1390.0
10-OCT	4.15	4.87	0.16	12.43	12.43	182.09	239.80	1366.2	1390.0
20-OCT	3.17	3.72	0.14	11.40	11.40	173.86	239.80	1362.5	1390.0
31-OCT	2.34	2.75	0.16	12.82	12.82	163.38	239.80	1357.7	1390.0
10-NOV	1.72	2.02	0.12	11.39	11.39	153.72	239.80	1353.0	1390.0
20-NOV	1.63	1.91	0.12	10.55	10.55	144.80	239.80	1348.5	1390.0
30-NOV	1.54	1.81	0.11	10.64	10.64	135.70	239.80	1343.7	1390.0
10-DEC	1.55	1.82	0.09	10.93	10.93	126.32	239.80	1338.7	1390.0
20-DEC	1.61	1.89	0.09	10.81	10.81	117.12	239.80	1333.6	1390.0
31-DEC	1.78	2.08	0.09	11.43	11.43	107.47	239.80	1328.0	1390.0
10-JAN	1.76	2.06	0.07	10.52	10.52	98.71	239.80	1322.5	1390.0
20-JAN	1.80	2.11	0.07	9.33	9.33	91.18	239.80	1317.5	1390.0
31-JAN	1.95	2.28	0.08	10.77	10.77	82.37	239.80	1311.5	1390.0
10-FEB	1.99	2.34	0.07	9.75	9.75	74.61	239.80	1305.4	1390.0
20-FEB	2.30	2.69	0.11	10.95	10.95	65.95	239.80	1298.0	1390.0
28-FEB	1.98	2.32	0.08	9.63	9.63	58.30	239.80	1290.7	1390.0
10-MAR	2.58	3.03	0.12	11.61	11.61	49.26	239.80	1280.9	1390.0
20-MAR	2.81	3.29	0.12	10.51	10.51	41.56	239.80	1269.1	1390.0
31-MAR	3.04	3.56	0.17	5.59	5.59	39.01	239.80	1264.9	1390.0
10-APR	2.27	2.66	0.18	0.54	0.54	40.74	239.80	1267.7	1390.0
20-APR	2.25	2.64	0.17	0	0	43.17	239.80	1271.6	1390.0
30-APR	2.34	2.74	0.16	1.85	1.85	43.66	239.80	1272.4	1390.0
10-MAY	2.62	3.07	0.24	4.88	4.88	41.41	239.80	1268.8	1390.0
20-MAY	3.00	3.52	0.27	4.72	4.72	39.69	239.80	1266.0	1390.0
31-MAY	3.29	3.85	0.25	7.04	7.04	35.94	239.80	1260.0	1390.0
TOTAL	261.85	306.95	5.74	330.14	330.14				

The conservation and upper rule levels are plotted in Figure-15

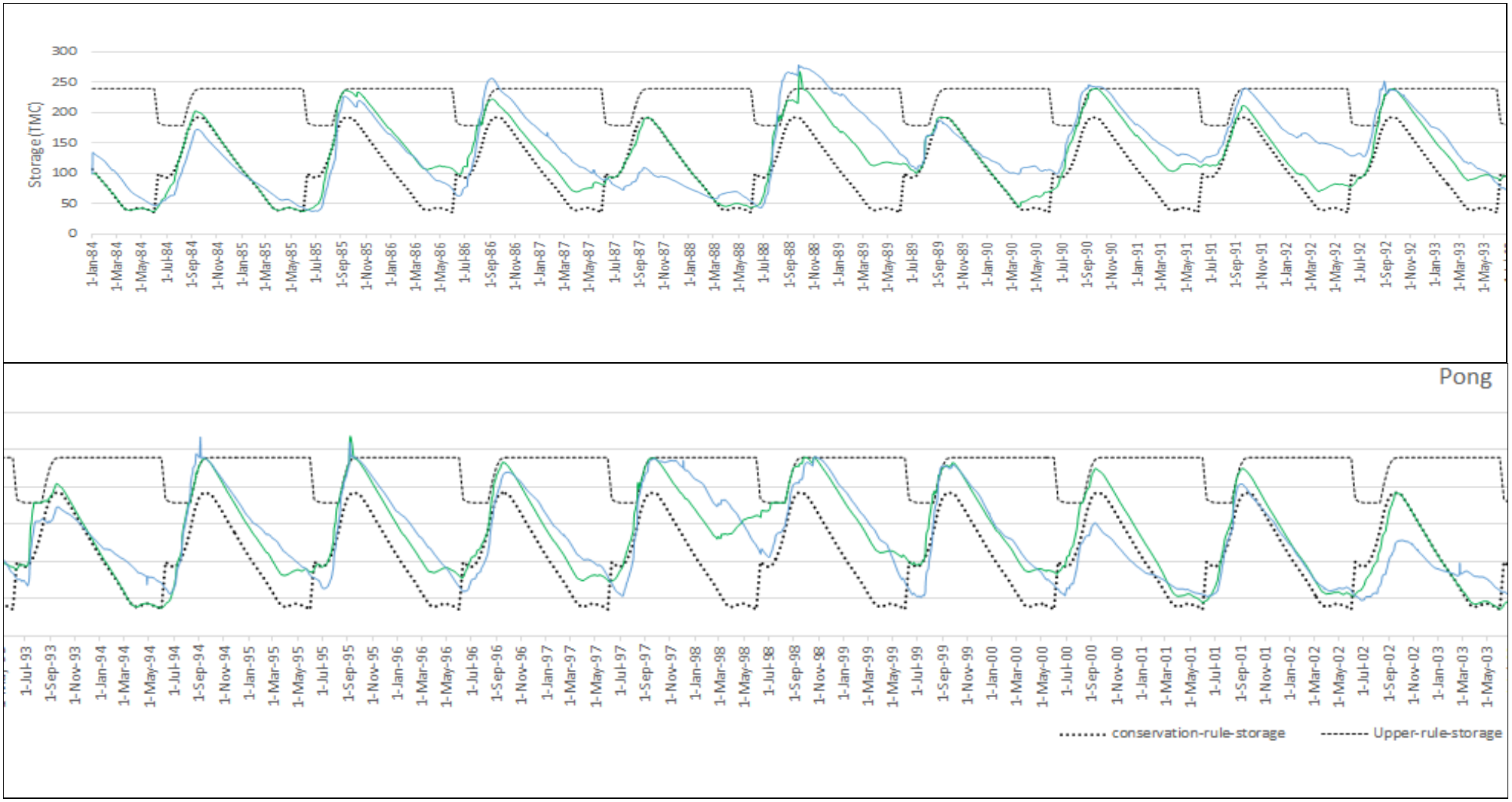


OP – FRL – Operative Full Reservoir Level

Fig 15: Rule Levels for Pong Reservoir (ft)

6.6 *Hindcast simulation chart*

The following Figures show the simulation chart on daily time steps. The green line shows the simulated storage if the reservoir is operated as per the rule curve whereas the blue line shows the actual storage derived from the daily reservoir level data provided by BBMB.



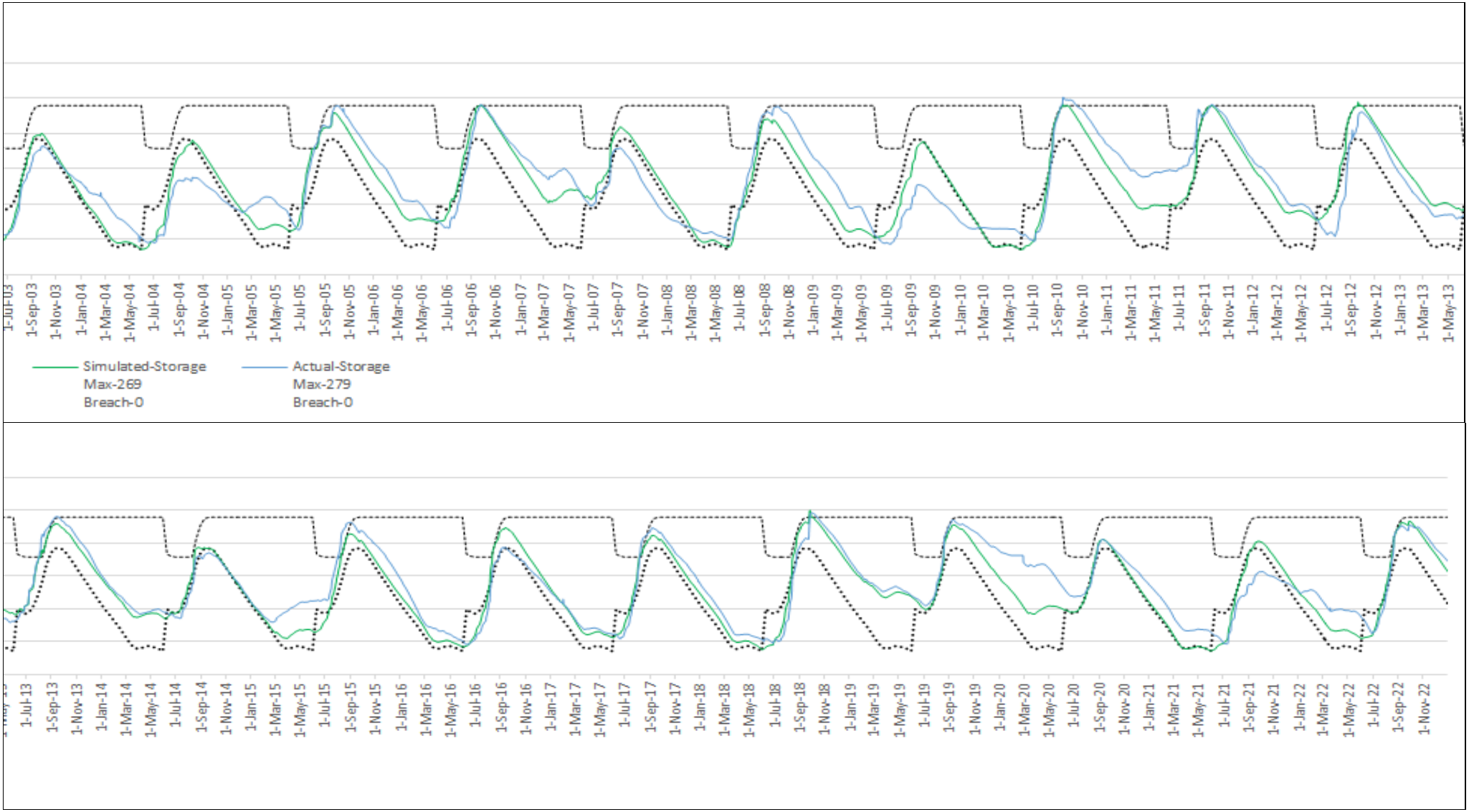


Fig 16: Conservation Rule storage, Upper Rule Storage , Simulated Storage and Actual Storage

6.7 Performance indices if operation rule is made based on Design FRL (1410 ft):

Table 13: Performance indices for conservation purposes:

Name of Dam/ Reservoir	Performance with operation rule		Performance without operation rule	
	Reliability (% days standard demand is fully met)	Vulnerability (avg. curtailment in demand when demand is not fully met)	Reliability (% days demand is fully met)	Vulnerability (avg. curtailment in demand when demand is not fully met)
Pong	92%	0.68 TMC	40%	0.38 TMC

Table 14: Performance indices for flood moderation purpose:

Name of Dam/ Reservoir	Performance with operation rule			Performance without operation rule	
	MRL/MWL breach events	Spill breach events	Observed maximum outflow (from all the outlets combined)	MRL/MWL breach events when limiting the spill to spillway capacity	Simulated maximum outflow (from all the outlets combined)
Pong	0	0	31-Jul-86 36,615 cusec	0	27-Sep-88 2,57,129 cusec

6.8 Performance indices if operation rule is made based on Operative FRL (1390 ft):

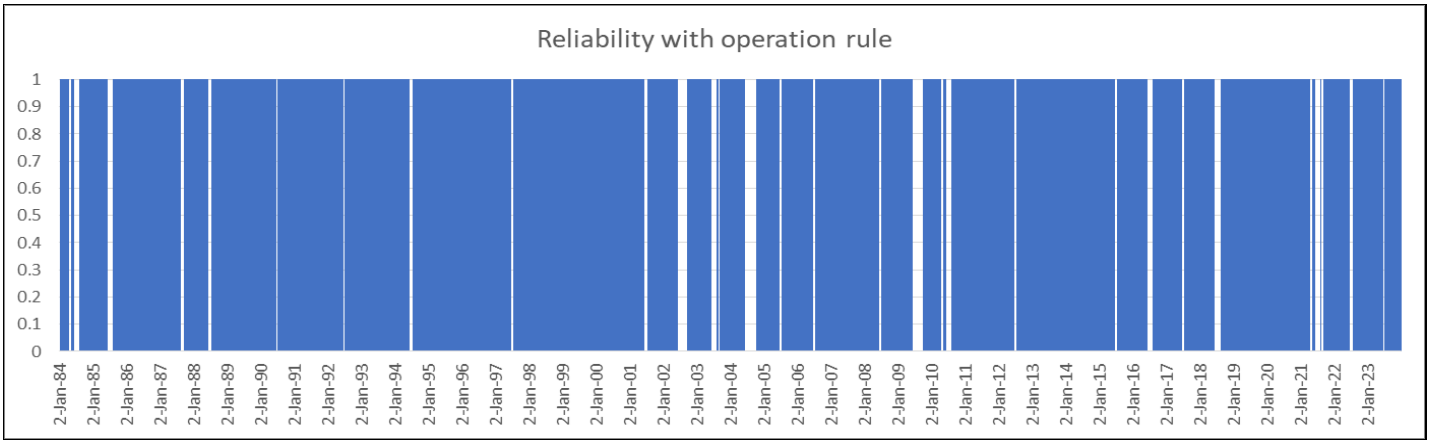
Table 15:Performance indices for conservation purposes:

Name of Dam/ Reservoir	Performance with operation rule		Performance without operation rule	
	Reliability (% days standard demand is fully met)	Vulnerability (avg. curtailment in demand when demand is not fully met)	Reliability (% days demand is fully met)	Vulnerability (avg. curtailment in demand when demand is not fully met)
Pong	89%	0.68 TMC	40%	0.38 TMC

Table 16: Performance indices for flood moderation purpose:

Name of Dam/ Reservoir	Performance with operation rule			Performance without operation rule	
	MRL/MWL breach events	Spill breach events	Observed maximum outflow (from all the outlets combined)	MRL/MWL breach events when limiting the spill to spillway capacity	Simulated maximum outflow (from all the outlets combined)
Pong	0	0	1-Oct-88 74,382 cusec	0	27-Sep-88 2,57,129 cusec

Following figures represents the performance (in terms of reliability) with and without operation Rule:
1 represents the demand is fully met on a particular day and 0 represents the demand is not met and needs to be curtailed.



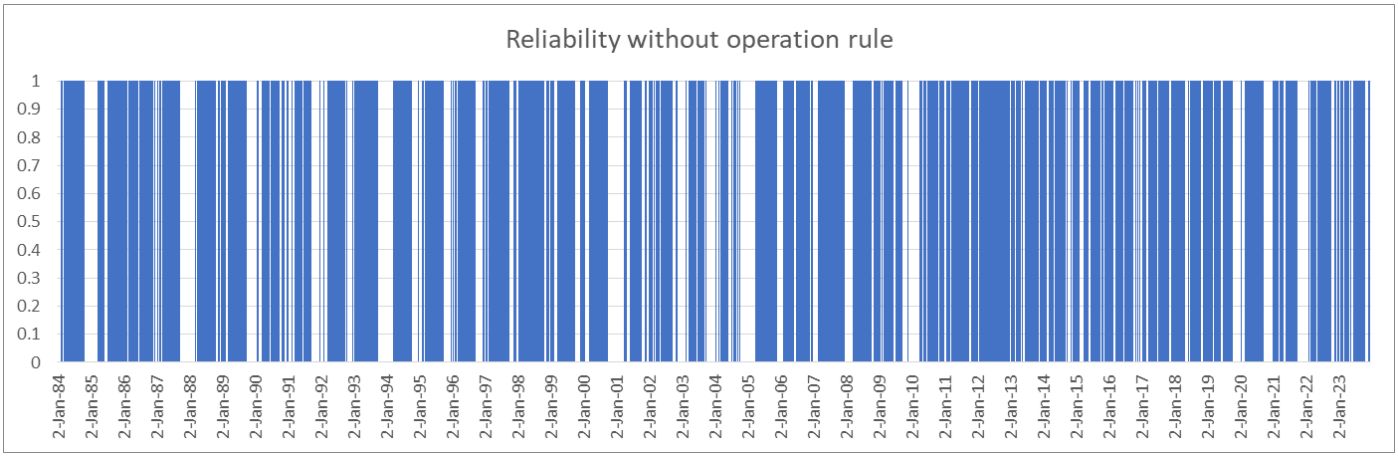


Fig 17: Reliability with and without operation rule based on Operative FRL

7 Operation of a Reservoir Using Rule Curves

After the derivation of initial rule curves for different purposes, the operation analysis is carried out for the reservoir and the rule curves are fine-tuned till the performance of the system can be improved. Finally derived rule curves are the operation rule curves which will be used to guide the operation of reservoir in actual field conditions.

The procedure for rule curve based operation is given in following steps:

i) At any time step, if the present water level in the reservoir exceeds level Upper Rule Level (URL), then spill is made from the reservoir and the water level is brought to URL.
ii) If the present reservoir level falls below URL but exceeds Conservation Rule Level i.e. Lower Rule Level (LRL), full supply is made for meeting all demands from the reservoir but no spill is made.
iii) If the present reservoir level falls below LRL, then release (full or partial) is made only for water supply demands and no release is made for irrigation or hydropower demands.

The underlying assumption in such an operation procedure is that it would always be better to supply less water throughout the year rather than meeting full demands for some time and then stopping the supply suddenly. The operation of a reservoir by strictly following the rule curves becomes quite rigid. Many times, due to various conditions like low inflows, minimum requirements for demands etc., it is not possible to stick to the rule with respect to storage levels. A flexible reservoir operation schedule can be maintained for those reservoirs which have adequate streamflow forecasting system. Further, in order to provide flexibility in operation, different rule curves can be developed to represent various scenarios.

Annexure -I

Table 17: Computation of Inflow data of Bhakra Reservoir at ten-daily time interval (in TMC ft.) from 1984-85 to 2022-23

Year	Jun-01	Jun-02	Jun-03	Jul-01	Jul-02	Jul-03	Aug-01	Aug-02	Aug-03	Sep-01	Sep-02	Sep-03	Oct-01	Oct-02	Oct-03	Nov-01	Nov-02	Nov-03
1998-1999	29.7	30.4	46.3	58.8	56.8	48.0	43.0	47.5	46.2	29.0	23.8	38.2	20.6	26.0	20.3	13.3	11.3	9.6
1994-1995	32.3	28.7	49.1	53.4	48.5	69.8	61.9	56.1	59.6	46.0	27.3	17.3	13.6	11.2	10.3	8.3	7.8	6.8
2010-2011	21.9	20.0	34.4	38.9	35.4	58.9	71.3	65.9	56.3	40.5	32.7	32.9	18.9	13.6	13.4	9.7	9.0	8.0
1990-1991	34.8	30.5	53.6	51.2	51.2	46.2	45.8	52.2	43.6	39.5	29.2	21.2	14.0	11.3	10.0	8.0	7.1	6.8
1988-1989	27.0	26.7	41.8	46.9	48.2	63.2	63.4	53.9	45.1	26.7	21.5	48.9	17.2	13.1	11.7	9.6	8.5	7.7
1991-1992	40.6	53.7	46.1	55.9	49.4	55.0	42.3	31.3	41.2	33.4	27.4	16.5	12.6	9.6	9.4	7.6	6.9	6.3
2005-2006	18.6	26.6	48.9	58.8	60.7	59.0	49.4	38.8	33.6	27.1	25.8	22.4	13.5	10.7	9.9	7.7	6.7	6.0
1995-1996	30.9	41.4	25.8	39.7	39.8	50.3	46.4	50.4	41.2	47.7	26.5	18.7	14.1	11.8	10.1	7.6	7.5	6.6
1989-1990	39.6	31.6	27.6	32.9	44.7	59.8	39.7	34.6	44.7	28.7	20.4	16.3	11.9	9.1	9.0	7.2	6.2	6.8
1986-1987	15.2	35.4	57.6	47.3	48.3	63.2	55.1	48.9	40.3	26.8	18.2	15.4	12.3	10.5	9.6	7.7	6.9	6.8
1992-1993	22.8	32.6	42.9	28.5	39.8	56.7	45.3	47.6	55.3	37.6	29.4	18.0	14.0	11.2	10.0	7.7	7.6	6.9
2013-2014	39.4	46.3	46.9	53.6	44.8	49.1	42.6	43.6	43.4	27.9	20.1	16.6	13.6	11.3	9.2	7.6	6.9	6.2
1996-1997	26.2	46.1	63.0	38.0	43.4	49.1	45.2	57.6	41.4	33.5	28.4	18.7	14.1	10.7	10.2	7.9	7.6	6.3
1999-2000	16.0	29.0	35.8	42.1	40.4	52.8	65.2	48.9	44.9	28.1	24.8	23.0	14.7	10.5	9.4	8.4	7.5	6.5
2019-2020	25.7	25.4	26.1	40.5	42.7	45.5	53.6	61.4	41.9	34.8	26.0	19.5	13.8	9.9	9.3	7.6	7.4	7.0
2011-2012	22.1	28.7	42.8	37.8	35.8	53.0	39.2	54.4	44.5	36.4	32.9	20.0	15.8	11.3	9.8	7.9	7.1	6.5
1987-1988	36.0	32.7	33.6	45.4	40.1	52.0	37.4	37.4	38.4	30.5	22.5	18.1	10.6	10.4	9.0	6.2	5.6	5.6
1997-1998	17.0	22.3	29.3	29.5	37.4	43.7	45.9	44.1	33.4	30.0	24.7	17.4	12.4	9.8	9.7	7.7	8.2	8.1
2002-2003	32.9	40.7	36.2	40.0	35.3	35.7	34.7	41.1	40.3	32.0	27.4	17.0	12.2	10.4	8.8	7.0	6.7	5.8
1985-1986	25.8	27.4	31.2	32.3	38.5	44.7	38.2	43.2	56.8	34.9	22.6	18.1	16.4	20.4	11.7	8.2	7.4	6.1
2008-2009	24.9	52.2	42.5	38.8	39.1	42.5	42.1	51.5	38.3	22.4	20.9	31.8	16.8	13.2	11.2	8.3	7.2	6.5
2003-2004	46.2	42.9	37.4	40.3	37.6	46.2	48.4	36.4	37.7	33.5	25.1	20.8	12.0	9.7	8.5	7.3	6.6	5.9
2015-2016	19.7	28.8	33.7	36.1	54.8	58.7	55.5	53.8	34.6	23.4	18.1	15.9	10.9	9.7	8.7	7.1	6.7	5.7
2018-2019	20.8	26.1	18.0	24.4	30.0	48.0	39.7	52.7	40.4	29.7	21.6	30.7	16.6	12.1	10.1	8.5	7.7	7.1
2014-2015	22.9	32.9	33.6	37.9	44.6	50.9	43.9	42.8	29.3	21.8	17.3	14.7	11.9	8.7	8.1	5.6	5.0	4.7
2012-2013	20.5	18.0	30.0	32.4	28.8	36.8	39.7	36.1	52.6	33.8	31.6	18.3	12.9	9.7	9.0	6.9	6.3	5.6
2016-2017	23.4	27.6	31.1	31.9	37.6	36.0	46.3	42.5	36.3	25.2	20.9	16.9	13.9	9.1	8.2	6.9	5.8	5.3
2006-2007	26.9	18.7	20.1	38.8	36.2	51.8	59.5	44.8	44.3	20.4	18.1	12.2	10.5	10.2	8.9	6.8	6.6	6.2
2001-2002	20.6	26.1	24.8	32.8	38.6	42.8	34.4	48.4	37.5	25.6	17.1	12.3	9.1	7.1	7.8	6.5	5.3	5.0
1993-1994	23.7	32.0	27.5	31.6	52.1	40.3	34.0	28.2	29.0	27.4	24.8	15.8	11.3	9.2	8.4	7.1	6.7	6.2
2000-2001	24.2	25.9	29.0	30.9	41.4	56.7	49.0	34.6	34.9	30.9	20.9	14.8	11.2	9.2	9.7	8.4	6.7	5.8
2020-2021	18.5	28.2	38.0	39.3	36.7	34.0	36.9	42.9	40.5	30.8	22.1	18.4	12.9	10.5	8.3	7.1	6.6	6.3
2017-2018	23.9	21.2	27.1	35.5	46.8	54.8	56.0	38.2	32.6	23.4	17.0	19.3	13.0	9.7	9.3	7.4	6.3	5.9
2021-2022	16.5	26.9	22.9	31.5	37.6	44.4	36.7	28.8	33.5	23.9	26.0	23.2	15.9	11.3	10.4	7.2	6.5	6.7
2009-2010	21.9	19.1	30.1	30.4	35.1	41.9	36.5	34.6	27.3	25.1	35.4	17.7	13.8	10.1	8.8	7.4	7.8	6.3
2022-2023	16.1	17.9	16.7	33.2	34.9	40.8	39.9	49.3	41.3	29.3	22.9	23.7	14.7	14.1	10.1	8.1	7.0	6.5
2007-2008	14.5	31.7	27.7	36.4	28.7	36.7	33.5	55.4	37.7	27.7	17.0	15.1	9.7	8.0	7.2	5.9	5.4	5.3
2004-2005	15.7	20.5	21.3	27.6	24.7	26.5	30.1	32.2	27.5	18.0	18.4	11.9	11.0	11.9	8.7	6.6	5.7	4.9

Year	Dec-01	Dec-02	Dec-03	Jan-01	Jan-02	Jan-03	Feb-01	Feb-02	Feb-03	Mar-01	Mar-02	Mar-03	Apr-01	Apr-02	Apr-03	May-01	May-02	May-03	Total
1998-1999	8.0	7.6	7.6	6.5	6.4	7.0	5.9	5.6	4.8	5.9	6.1	6.7	7.4	10.7	17.9	19.3	20.9	30.1	783.5
1994-1995	6.7	6.2	6.4	5.8	5.3	5.2	4.8	6.1	4.1	4.5	4.3	8.8	7.2	8.7	11.5	13.3	28.7	20.9	766.3
2010-2011	6.9	6.4	7.6	6.5	5.8	5.7	5.6	7.0	4.5	7.8	7.1	8.9	7.3	9.2	11.7	17.8	21.5	29.1	758.1
1990-1991	6.5	5.9	7.7	7.0	5.7	5.6	5.4	6.7	5.5	8.4	8.7	11.8	13.2	12.4	14.3	19.1	23.4	31.1	754.6
1988-1989	6.8	6.0	10.5	9.9	7.3	6.7	6.4	5.6	4.5	6.0	6.1	9.6	8.2	8.6	8.5	11.5	16.5	27.6	747.5
1991-1992	6.5	5.8	6.6	5.5	5.9	7.0	8.7	6.9	5.2	6.1	7.6	12.1	9.3	10.7	14.2	16.0	21.3	22.6	723.4
2005-2006	5.6	5.3	5.2	5.0	5.4	5.2	5.0	5.0	4.0	4.5	6.0	5.9	6.2	7.1	11.1	21.9	31.3	39.5	703.4
1995-1996	6.2	6.6	6.0	5.5	5.7	6.4	5.0	5.5	5.5	4.4	8.1	10.3	8.6	13.1	19.1	18.8	16.9	26.7	694.9
1989-1990	5.9	5.0	6.7	4.8	4.4	5.4	4.8	6.2	4.4	6.0	7.3	15.5	10.9	13.2	15.8	19.6	39.4	39.6	686.0
1986-1987	6.5	7.2	6.2	5.3	6.8	5.7	5.4	5.1	5.1	6.3	6.1	8.0	8.3	8.4	12.4	17.5	18.2	20.6	684.4
1992-1993	5.9	5.7	5.8	5.6	6.1	5.2	5.2	5.4	4.2	5.1	7.3	10.5	7.4	10.1	15.3	21.9	15.9	23.3	679.8
2013-2014	5.9	5.6	5.8	4.5	5.4	6.0	4.7	5.8	4.4	5.5	5.3	8.5	9.4	10.9	10.3	15.6	16.8	17.9	677.4
1996-1997	6.2	5.4	5.9	4.7	5.2	5.3	5.0	4.2	3.5	4.0	4.9	5.7	7.0	8.4	10.7	13.7	10.7	15.0	672.7
1999-2000	6.5	5.6	5.9	5.5	5.7	5.8	5.2	5.7	4.3	5.0	5.2	7.2	8.0	8.8	10.5	13.4	22.4	26.0	664.6
2019-2020	6.3	6.7	6.3	5.8	6.5	6.7	5.6	6.2	5.4	5.9	9.1	9.6	8.6	10.3	11.3	15.0	16.8	20.5	660.5
2011-2012	6.3	6.0	5.8	5.1	6.3	5.8	4.3	5.2	4.5	6.8	5.2	8.2	9.7	8.9	10.2	9.7	13.7	18.6	646.2
1987-1988	5.2	4.3	4.8	3.8	4.2	4.0	3.5	3.3	3.9	4.6	8.2	7.5	7.4	15.6	17.4	22.8	25.2	27.9	645.1
1997-1998	9.4	8.1	6.9	6.0	5.6	6.1	4.8	6.3	7.6	11.5	12.2	11.5	13.7	12.5	17.5	19.6	19.4	34.0	643.4
2002-2003	5.0	4.9	4.9	4.3	3.7	4.2	4.1	4.1	3.8	7.1	5.5	8.2	7.8	12.3	14.1	15.6	26.6	37.4	638.1
1985-1986	5.6	5.8	6.7	5.5	5.0	4.9	4.6	4.8	4.7	5.3	7.1	7.1	7.0	11.2	14.3	14.2	22.4	16.5	636.7
2008-2009	6.6	6.0	6.4	5.5	5.0	5.2	5.0	4.5	3.6	4.1	4.0	4.9	5.5	5.8	6.7	10.3	12.1	23.1	634.5
2003-2004	5.5	5.5	4.8	4.5	3.8	6.1	4.5	4.3	4.5	4.6	6.2	7.3	7.0	6.2	9.2	9.2	14.3	18.4	628.5
2015-2016	5.9	6.3	5.4	5.1	5.2	4.8	4.7	4.4	4.2	5.6	6.6	6.8	8.0	7.2	8.1	13.2	20.9	24.0	628.4
2018-2019	6.3	5.7	6.0	5.2	5.0	5.8	6.9	7.1	7.8	7.7	6.8	9.8	13.0	14.0	16.8	15.7	16.9	20.1	621.0
2014-2015	4.2	4.6	4.3	4.2	4.3	4.1	4.1	3.7	4.9	7.9	6.6	10.0	11.7	11.2	15.8	17.6	24.7	26.9	607.3
2012-2013	5.8	5.5	5.0	4.3	5.1	4.8	6.7	6.0	5.2	6.9	7.2	10.5	9.0	10.3	11.7	12.2	17.7	35.4	598.4
2016-2017	5.0	5.1	5.2	5.3	4.8	6.0	5.0	3.8	3.7	4.1	4.6	6.3	9.2	11.1	20.6	13.1	22.1	27.0	587.0
2006-2007	5.7	4.9	5.2	4.5	3.8	4.4	3.8	5.0	3.5	6.3	8.6	10.1	9.5	11.0	10.8	13.9	16.9	16.8	585.7
2001-2002	4.8	4.5	5.4	4.1	4.1	5.0	3.6	5.1	3.4	7.6	7.2	9.2	9.1	10.4	14.6	17.3	35.8	31.8	584.7
1993-1994	5.7	5.3	5.4	4.3	4.8	5.3	4.5	4.6	4.4	4.3	6.1	6.8	9.2	7.5	8.2	14.3	15.5	30.1	561.5
2000-2001	5.5	4.8	5.6	4.7	4.1	4.1	3.6	3.4	3.2	4.2	4.1	5.8	5.3	6.0	7.4	10.9	17.2	16.8	561.0
2020-2021	5.7	5.6	6.3	4.9	4.9	6.3	4.9	5.1	4.5	4.9	6.2	6.3	6.1	5.2	9.0	11.2	11.9	13.3	560.4
2017-2018	5.7	5.9	5.6	5.1	4.4	5.3	4.7	4.9	4.1	4.5	4.2	5.2	5.5	5.8	7.8	9.3	9.8	13.7	558.9
2021-2022	6.3	5.6	6.2	6.3	5.3	6.2	5.3	5.3	4.9	6.0	8.4	9.8	10.0	9.6	9.3	12.0	18.4	12.8	557.3
2009-2010	5.5	5.4	5.6	4.6	4.8	4.4	4.8	4.8	4.1	5.5	5.8	8.5	6.9	9.2	11.1	17.4	14.6	22.0	554.2
2022-2023	6.6	5.8	5.4	4.6	4.8	4.8	5.0	4.5	4.2	5.4	5.3	6.1	6.3	7.7	10.2	10.2	10.0	15.7	549.0
2007-2008	4.8	4.2	4.8	3.8	4.6	4.4	3.1	3.4	2.8	4.6	5.4	5.8	5.9	7.7	9.5	13.0	16.0	21.7	529.1
2004-2005	5.0	4.8	4.7	4.9	4.3	4.7	4.8	7.4	4.6	6.7	9.3	12.1	8.7	9.3	15.1	18.1	17.8	16.3	481.6

Annexure-II

Table 18: Computation of Inflow data of Pong reservoir at ten-daily time interval (in TMC ft.) from 1984-2023

Year	Jun-01	Jun-02	Jun-03	Jul-01	Jul-02	Jul-03	Aug-01	Aug-02	Aug-03	Sep-01	Sep-02	Sep-03	Oct-01	Oct-02	Oct-03	Nov-01	Nov-02
1988-1989	3.2	2.9	13.6	22.4	41.0	66.8	76.8	42.2	26.9	11.1	6.8	87.6	13.2	6.8	3.3	2.5	2.2
1997-1998	2.8	3.6	10.0	14.2	30.2	28.9	48.5	69.0	35.1	29.0	15.7	7.6	5.9	3.5	3.6	3.1	3.4
1994-1995	4.9	4.8	17.1	37.2	29.7	56.8	43.7	58.3	54.6	29.9	12.5	5.1	3.4	2.3	2.3	1.8	1.6
1995-1996	8.7	10.7	5.1	11.9	21.7	50.6	46.7	51.7	34.9	81.4	14.9	6.3	4.1	2.7	2.2	1.9	1.7
1990-1991	6.7	5.0	19.1	36.1	36.9	27.0	35.4	49.7	25.7	36.2	21.0	10.3	5.6	3.7	3.3	2.3	2.0
1999-2000	1.4	3.9	9.4	12.1	19.3	64.3	63.7	51.4	52.4	14.1	11.6	13.6	4.8	3.0	2.7	1.9	1.8
2013-2014	6.2	13.3	16.5	32.8	21.0	46.9	62.6	38.5	28.0	17.1	9.1	6.1	6.0	4.4	2.4	2.8	2.7
2018-2019	3.3	3.1	4.8	8.1	14.0	33.6	37.4	52.7	39.8	20.8	12.6	50.7	7.8	4.6	3.9	2.3	2.5
1998-1999	6.1	18.6	10.8	28.3	38.2	21.8	21.3	40.2	39.3	12.3	15.3	32.4	9.0	17.1	6.7	3.5	2.9
1986-1987	2.0	7.2	23.9	26.5	25.8	46.8	53.2	48.3	25.6	11.7	3.8	4.5	5.2	4.8	2.7	2.3	2.8
1992-1993	3.9	6.8	10.4	6.6	19.6	34.1	50.5	50.3	57.8	24.3	24.1	6.9	4.1	3.5	2.3	1.8	2.0
1985-1986	2.3	2.9	4.7	7.4	25.8	37.0	27.8	44.5	68.8	32.5	10.6	7.6	10.0	12.2	4.3	2.9	2.5
2012-2013	2.5	2.3	5.9	12.3	10.4	27.3	41.6	40.9	71.4	23.4	35.2	13.4	4.9	3.5	2.7	2.9	2.1
2010-2011	2.9	2.8	4.6	17.4	13.4	29.0	40.3	53.3	47.8	27.9	28.4	12.2	4.4	2.7	2.9	2.0	1.8
2006-2007	3.4	1.5	7.1	19.7	14.4	36.3	37.0	28.3	39.0	25.6	26.8	10.9	5.4	3.0	3.5	2.3	2.0
2011-2012	5.6	8.9	13.8	14.8	15.2	30.9	30.2	74.4	38.0	21.7	18.6	6.9	4.5	2.8	2.4	1.6	1.8
2005-2006	2.1	3.3	14.1	42.8	43.6	37.0	32.1	29.1	17.1	10.5	29.4	12.0	4.6	3.3	2.6	1.7	1.8
2022-2023	2.4	1.2	3.0	17.4	25.9	27.9	39.0	48.4	47.5	18.0	9.2	15.3	5.5	4.6	3.0	2.3	2.1
2008-2009	5.2	26.7	20.1	22.2	29.4	22.5	40.0	43.0	28.3	10.3	5.8	12.5	4.0	2.9	2.6	1.5	1.7
1996-1997	2.6	12.3	21.8	13.8	18.9	22.4	23.2	50.1	39.4	21.2	17.4	5.6	4.2	3.0	2.4	1.8	1.4
2019-2020	3.1	3.4	4.5	9.8	13.5	25.8	31.6	58.9	28.6	19.6	9.1	7.5	7.0	4.0	2.7	2.1	2.3
2017-2018	6.3	1.8	12.5	15.5	35.6	38.8	72.3	28.0	18.6	15.1	6.6	8.5	4.0	2.8	2.3	2.1	1.5
2001-2002	3.4	7.2	9.8	19.9	35.1	37.7	23.4	56.6	28.4	12.9	6.4	3.5	2.7	1.9	2.0	2.0	1.7
2015-2016	2.1	4.1	11.6	13.5	36.2	41.1	53.1	40.3	21.0	7.5	3.8	9.3	3.1	3.1	2.6	1.9	1.6
1991-1992	7.4	13.2	8.2	11.1	13.5	20.6	27.9	19.3	31.0	21.9	22.6	5.8	3.3	2.3	2.1	1.6	1.8
2016-2017	1.8	6.4	9.2	15.6	19.5	23.9	58.4	40.1	26.6	14.0	11.3	6.0	3.2	2.7	1.9	2.0	1.9
2014-2015	4.8	9.6	7.5	11.5	24.1	31.9	28.4	46.8	10.4	10.8	5.5	4.1	3.5	2.3	2.9	2.3	1.8
2000-2001	5.8	5.6	16.4	23.9	24.8	45.6	30.9	23.8	27.8	21.0	8.1	5.9	3.6	2.5	2.6	2.0	1.7
1993-1994	3.7	8.9	9.2	13.4	80.7	32.0	15.6	9.8	14.0	21.5	17.3	5.8	3.7	2.4	1.9	1.6	1.5
1989-1990	9.5	6.0	4.4	5.2	15.8	41.7	28.9	12.9	29.3	10.9	6.2	4.9	2.3	2.6	1.9	1.4	1.2
2021-2022	2.7	6.5	2.2	6.1	36.5	31.8	24.2	13.3	28.1	12.4	20.9	11.0	8.2	3.6	4.0	2.6	2.1
2007-2008	2.1	9.1	10.6	26.4	15.1	21.3	18.9	50.4	20.5	14.9	6.4	6.4	4.0	3.2	3.9	1.9	2.3
2003-2004	5.9	5.6	8.2	9.5	15.9	22.6	41.5	19.2	24.9	20.7	12.4	11.7	3.9	2.4	2.1	2.1	1.6
1984-1985	7.8	12.3	9.0	13.0	9.3	36.3	24.4	24.9	30.0	24.7	8.7	5.4	3.3	2.2	1.8	1.0	1.2
2004-2005	1.3	5.9	5.3	13.7	6.7	21.6	36.2	25.6	15.2	4.9	9.4	4.0	11.1	6.0	3.8	2.5	2.1
2020-2021	5.0	5.6	10.4	12.5	12.2	16.8	18.6	36.7	38.9	15.2	7.9	3.5	2.7	2.8	2.2	1.5	1.5
2002-2003	2.1	5.4	5.8	11.9	8.2	11.7	17.0	22.4	25.5	16.9	17.7	4.7	3.1	2.5	2.2	1.4	1.3
1987-1988	9.5	8.9	5.3	8.9	10.0	20.2	11.0	12.1	22.9	16.4	8.7	3.2	1.9	2.5	3.0	1.5	1.1
2009-2010	1.8	1.2	3.8	4.1	9.4	21.6	23.7	15.2	6.7	24.5	20.5	4.4	3.2	2.2	2.0	2.0	3.7

Year	Dec-01	Dec-02	Dec-03	Jan-01	Jan-02	Jan-03	Feb-01	Feb-02	Feb-03	Mar-01	Mar-02	Mar-03	Apr-01	Apr-02	Apr-03	May-01	May-02	May-03	Total
1988-1989	1.3	1.4	5.2	7.5	3.4	2.6	3.3	2.8	1.7	1.9	2.3	4.4	2.9	2.6	2.7	3.5	3.9	5.7	489.7
1997-1998	4.8	4.8	3.5	2.7	2.3	2.3	2.0	4.8	9.5	15.2	10.1	6.7	7.1	5.8	8.3	7.5	5.5	9.4	431.1
1994-1995	1.6	1.4	2.3	1.9	2.2	1.9	1.8	5.3	1.8	2.3	2.1	3.7	3.0	3.3	4.0	3.2	7.5	3.1	419.9
1995-1996	1.6	1.5	1.4	1.4	2.8	2.1	1.9	2.5	3.6	2.8	4.7	4.1	3.2	2.9	3.5	2.2	2.1	1.7	404.3
1990-1991	1.7	2.0	3.9	4.5	2.2	2.1	2.4	3.8	2.6	4.5	4.0	3.9	4.0	7.2	3.6	4.7	4.8	4.3	394.4
1999-2000	1.8	1.4	2.3	1.7	3.9	2.6	2.9	3.1	2.2	2.7	2.8	3.3	2.5	2.2	2.0	2.3	5.2	4.9	383.1
2013-2014	1.8	2.0	3.3	2.2	1.7	3.9	2.3	4.3	2.3	3.4	3.4	4.8	3.1	2.6	2.6	4.9	4.0	2.2	373.3
2018-2019	2.2	1.8	2.3	2.0	2.2	4.3	6.3	5.8	6.4	4.5	3.8	3.6	3.9	3.7	3.4	3.4	2.7	4.1	371.0
1998-1999	2.1	2.1	1.8	1.8	1.7	3.1	2.0	2.3	1.8	1.9	1.9	1.7	1.3	1.5	1.9	1.8	0.9	6.6	364.7
1986-1987	2.8	3.3	2.3	2.0	4.3	2.9	2.2	2.5	2.5	2.4	2.9	2.9	2.8	3.0	3.0	8.1	10.9	4.0	364.3
1992-1993	1.8	1.7	1.2	2.3	2.6	2.5	2.0	2.2	1.4	2.3	4.1	6.5	2.5	3.3	3.7	5.4	2.6	4.3	363.2
1985-1986	2.1	2.1	4.6	2.3	2.3	1.9	2.0	2.3	3.1	2.5	3.2	3.2	2.4	2.7	3.8	3.3	3.9	4.7	358.0
2012-2013	2.2	2.4	2.4	1.9	2.0	3.0	3.2	2.8	2.3	3.3	2.8	3.0	3.1	1.7	1.7	1.5	1.3	5.8	351.3
2010-2011	1.8	1.5	1.5	2.5	2.0	1.8	2.6	4.6	2.1	3.5	3.1	3.5	1.6	3.2	3.5	4.4	4.5	6.9	350.4
2006-2007	2.2	2.4	1.9	1.5	1.3	1.3	1.4	2.2	2.1	5.9	10.7	8.2	5.6	6.3	4.6	5.4	4.8	3.6	339.5
2011-2012	1.8	1.7	1.4	2.2	4.2	2.3	2.4	2.4	2.3	3.0	2.2	3.5	2.1	1.7	2.1	2.2	2.0	2.2	335.6
2005-2006	1.4	1.5	1.6	1.8	2.5	2.0	2.4	2.2	1.7	1.9	3.7	2.1	1.8	1.4	2.0	2.9	4.5	5.7	331.8
2022-2023	2.2	1.7	1.7	1.4	1.6	3.7	1.7	2.3	2.4	2.8	2.3	2.8	2.6	1.7	1.9	3.8	2.6	3.7	317.8
2008-2009	1.8	1.7	1.7	1.5	2.2	2.1	2.0	2.2	1.4	1.8	1.2	2.2	2.0	2.3	1.4	2.0	1.5	2.1	313.5
1996-1997	1.4	1.3	1.5	1.7	1.6	2.7	1.9	1.8	1.6	2.2	3.2	3.1	3.9	3.3	2.9	5.0	2.9	2.0	307.0
2019-2020	2.2	4.0	2.3	2.7	3.8	3.0	2.5	2.4	2.4	3.1	8.7	6.8	4.8	3.8	4.3	4.5	4.3	4.4	305.9
2017-2018	2.0	3.4	2.7	2.1	1.7	1.8	1.5	2.0	1.2	1.4	0.9	1.2	1.4	1.7	1.2	1.3	1.7	1.2	303.9
2001-2002	2.0	1.7	1.9	1.7	1.9	2.6	2.1	2.0	1.4	2.9	1.8	2.1	1.3	1.4	2.5	1.8	7.2	3.6	298.3
2015-2016	1.9	2.2	2.7	2.4	2.0	1.6	2.2	1.9	2.0	1.2	2.9	2.5	1.6	1.5	1.3	1.5	2.2	3.4	294.8
1991-1992	1.6	1.5	1.8	1.9	2.6	4.3	9.0	5.8	3.0	3.2	3.6	7.8	4.1	3.8	4.4	4.2	4.8	4.9	287.2
2016-2017	1.3	1.8	1.6	1.9	1.8	3.0	2.6	1.9	1.7	1.2	1.8	1.8	2.3	2.3	2.6	1.1	3.1	4.2	284.0
2014-2015	2.1	2.7	2.0	1.6	2.0	2.1	2.4	1.9	4.3	8.9	5.1	4.5	6.1	4.6	4.9	4.4	5.7	4.9	280.0
2000-2001	1.7	1.5	1.6	1.4	1.0	1.1	0.8	1.0	0.7	0.7	0.7	1.3	1.3	1.6	2.7	1.3	2.2	2.1	278.9
1993-1994	1.4	1.1	1.3	1.0	1.6	1.2	1.1	1.5	2.3	1.3	1.3	1.4	3.2	1.6	1.4	2.5	2.2	5.3	277.1
1989-1990	1.8	1.5	3.3	1.4	1.2	1.4	1.9	3.6	2.2	3.0	3.6	14.1	4.0	4.1	4.0	3.6	11.9	8.7	261.9
2021-2022	1.4	1.6	1.6	3.8	3.2	3.3	3.5	2.6	2.1	3.0	3.3	3.7	1.5	1.1	1.2	1.4	1.6	2.2	260.1
2007-2008	2.3	2.2	1.7	1.2	2.3	1.9	2.0	1.8	1.5	2.3	1.8	1.6	1.3	2.0	1.7	1.6	1.6	3.9	253.6
2003-2004	1.4	1.6	1.2	1.2	1.8	3.7	3.0	2.2	2.6	2.5	2.6	1.6	0.8	1.3	1.2	2.8	1.4	2.0	246.5
1984-1985	1.3	1.5	1.5	2.7	2.0	1.8	1.7	1.4	0.7	0.9	0.7	0.8	1.6	2.6	1.6	1.2	0.8	4.4	245.7
2004-2005	1.9	1.9	2.3	2.2	1.5	2.8	3.3	5.8	3.7	3.5	4.7	6.1	3.0	2.8	3.3	3.8	2.5	2.6	234.3
2020-2021	1.8	1.9	2.5	2.8	1.6	1.9	1.5	2.0	1.3	1.4	1.1	1.2	0.9	0.9	2.4	2.2	2.7	1.9	227.8
2002-2003	1.6	1.1	1.1	0.8	0.7	0.9	1.5	3.0	2.0	5.4	2.4	2.1	2.2	2.1	2.3	1.7	1.4	2.8	196.9
1987-1988	0.9	0.8	1.2	1.1	1.2	1.0	1.2	1.2	1.9	2.6	9.0	3.2	2.3	2.8	2.5	2.9	3.8	2.8	190.4
2009-2010	1.8	1.6	1.4	1.8	1.2	1.0	1.1	1.8	1.0	1.7	1.1	1.4	0.8	0.9	1.2	1.5	1.3	1.7	176.0